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SZABMU ISLAMABAD

SZABMU Islamabad MDCAT 2022 Official Paper

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

🛡️ Official Admitting Board: Shaheed Zulfiqar Ali Bhutto Medical University Islamabad 📁 Archive Code: BEAMBE-FLP-SZABMU-2022

🕒 Duration: 200 Minutes (3h 20m)

200

TOTAL QUESTIONS

200m

OFFICIAL DURATION

+1 / 0.00

ZERO NEGATIVE MARKING

200

MAXIMUM MARKS

📄 EXAMINATION BLUEPRINT & SUBJECT WEIGHTAGE

Biology**68 MCQs**

34.0% weight

Chemistry**54 MCQs**

27.0% weight

Physics**54 MCQs**

27.0% weight

English**18 MCQs**

9.0% weight

Logical Reasoning**6 MCQs**

3.0% weight

BIO SECTION: BIOLOGY

Questions 1 to 68 (68 MCQs)

Q1. BIO

Each granum in a chloroplast typically consists of how many thylakoids?

- (A) 40 to 60
- (B) 25 to 50
- (C) 50 to 70
- (D) 100 to 200

Q2. BIO

The specialized terminal ends of eukaryotic chromosomes are called:

- (A) Satellites
- (B) Kinetochores
- (C) Nucleolar organizers
- (D) Telomeres

Q3. BIO

Which cellular organelle is markedly more abundant in secretory cells compared to non-secretory cells?

- (A) Lysosomes
- (B) Golgi complex
- (C) Central vacuoles
- (D) Centrioles

Q4. BIO

Which nuclear structure disassembles and disappears during the early stages of cell division?

- (A) Vacuoles
- (B) Lysosomes
- (C) Nucleolus
- (D) Endoplasmic reticulum

Q5. BIO

The enzyme ATP synthase complex is embedded within the membrane of which organelle?

- (A) Nucleus
- (B) Mitochondria
- (C) Lysosome
- (D) Vacuole

Q6. BIO

Intracellular digestion of foreign particles and cellular debris is executed by which organelle?

- (A) Vacuoles
- (B) Lysosomes
- (C) Golgi apparatus
- (D) Ribosomes

Q7. BIO

Which of the following axons conducts an action potential with the highest velocity?

- (A) 1 mm diameter neuron, lacking myelin
- (B) 1 mm diameter neuron, with myelin
- (C) 2 mm diameter neuron, lacking myelin
- (D) 2 mm diameter neuron, with myelin

Q8. BIO

Chemically, vasopressin (antidiuretic hormone) is classified as a:

- (A) Steroid hormone
- (B) Catecholamine
- (C) Peptide hormone
- (D) Glycoprotein

Q9. BIO

Which physiological process is NOT under the direct control of the hypothalamus?

- (A) Regulation of hunger
- (B) Regulation of sleep-wake cycles
- (C) Regulation of water balance
- (D) Storage of long-term memory

Q10. BIO

Which hormone is stored and secreted by the posterior lobe of the pituitary gland?

- (A) Oxytocin
- (B) Thyroid-stimulating hormone
- (C) Adrenocorticotrophic hormone
- (D) Follicle-stimulating hormone

Q11. BIO

In the nervous system, action potentials are propagated across a chemical synapse via molecules known as:

- (A) Communicators
- (B) Neurotransmitters
- (C) Nerve impulses
- (D) Nociceptors

Q12. BIO

The microscopic functional junction between two neurons is termed a:

- (A) Synapsis
- (B) Synapse
- (C) Collapse
- (D) Synaptic knob

Q13. BIO

In a somatic spinal reflex arc, the cell bodies of sensory afferent neurons are situated within the:

- (A) Ventral root ganglion
- (B) Grey matter of the spinal cord
- (C) White matter of the spinal cord
- (D) Dorsal root ganglion

Q14. BIO

Basic emotional drives including feelings of love, anger, fear, and hate are primarily processed by the:

- (A) Amygdala
- (B) Hippocampus
- (C) Thalamus
- (D) Hypothalamus

Q15. BIO

Which of the following statements correctly characterizes Amoeba?

- (A) They move through coordinated flagellar beating
- (B) They possess a multicellular organization
- (C) They are entirely harmless and incapable of causing human disease
- (D) They locomote via pseudopodia formation

Q16. BIO

Negative feedback homeostatic mechanisms for endothermic thermoregulation are characteristic of:

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

Q17. BIO

The catalytic activity of an enzyme molecule is confined to a specialized localized region termed the:

- (A) Active site
- (B) Passive site
- (C) Allosteric site
- (D) Regulatory site

Q18. BIO

The proteolytic enzyme trypsin exhibits maximum enzymatic activity at approximately which pH?

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

Q19. BIO

Most enzymes operating within the human body display an optimum catalytic temperature near:

- (A) 30 °C
- (B) 40 °C
- (C) 50 °C
- (D) 20 °C

Q20. BIO

Enzymes accelerate the rate of biochemical reactions primarily by lowering the:

- (A) Kinetic energy of reactants
- (B) Activation energy barrier
- (C) Total heat energy released
- (D) Potential energy of products

Q21. BIO

In enzyme thermodynamics, the term 'maximum temperature' refers to the temperature threshold above which the enzyme:

- (A) Starts to undergo thermal denaturation
- (B) Begins spontaneous renaturation
- (C) Exhibits its highest catalytic efficiency
- (D) Becomes reactivated after inhibition

Q22. BIO

Which molecule decreases enzymatic reaction rates by competing directly with the substrate for the active site due to structural complementarity?

- (A) Competitive inhibitor
- (B) Non-competitive inhibitor
- (C) Coenzyme
- (D) Allosteric activator

Q23. BIO

Who formulated the theory of evolution explaining the origin of species by means of natural selection?

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

Q24. BIO

Geological strata reveal that the oldest known microfossils, dating back roughly 3.5 billion years, represent:

- (A) Prokaryotes
- (B) Amphibians
- (C) Reptiles
- (D) Fishes

Q25. BIO

What is the primary gastrointestinal action exerted by the peptide hormone cholecystokinin (CCK)?

- (A) Contraction of the gallbladder to discharge stored bile
- (B) Stimulation of mucus release from gastric goblet cells
- (C) Direct induction of bile production by hepatic lobules
- (D) Stimulation of hydrochloric acid release from gastric glands

Q26. BIO

Which of the following chemical entities is absent in human hepatic bile?

- (A) Digestive enzymes
- (B) Bile salts
- (C) Mucus
- (D) Lecithin

Q27. BIO

The initial enzymatic cleavage of polypeptide chains occurs in which organ of the human digestive tract?

- (A) Mouth
- (B) Oesophagus
- (C) Stomach
- (D) Small intestine

Q28. BIO

At a normal resting heart rate of 75 beats per minute, the duration of a single cardiac cycle is:

- (A) 0.6 s
- (B) 0.4 s
- (C) 0.7 s
- (D) 0.8 s

Q29. BIO

Which hormone acts directly on the gastric mucosa to stimulate hydrochloric acid secretion from parietal cells and pepsinogen from chief cells?

- (A) Cholecystokinin
- (B) Secretin
- (C) Gastrin
- (D) Somatostatin

Q30. BIO

The route of water and mineral transport that traverses adjacent plant cells through cytoplasmic strands called plasmodesmata is the:

- (A) Apoplast pathway
- (B) Symplast pathway
- (C) Vacuolar pathway
- (D) Ascent of sap pathway

Q31. BIO

The inactive pancreatic proenzyme trypsinogen is converted into active trypsin in the duodenum by the brush-border enzyme:

- (A) Hydrochloric acid
- (B) Pepsin
- (C) Enterokinase (enteropeptidase)
- (D) Erepsin

Q32. BIO

The breakdown of large dietary lipid droplets into minute, suspended droplets (emulsification) is mediated by:

- (A) Pancreatic lipase
- (B) Bile salts
- (C) Trypsin
- (D) Chymotrypsin

Q33. BIO

The central anatomical compartment of the thoracic cavity situated between the two pleural sacs is termed the:

- (A) Periosteum
- (B) Infundibulum
- (C) Mediastinum
- (D) Pulmonary hilum

Q34. BIO

Oxygenated blood returning to the human heart from the lungs enters the left atrium via:

- (A) Superior vena cava
- (B) Inferior vena cava
- (C) Coronary sinus
- (D) Four pulmonary veins

Q35. BIO

Because viruses lack autonomous metabolic machinery and cannot reproduce outside a host cell, they are all classified as:

- (A) Obligate autotrophs
- (B) Facultative heterotrophs
- (C) Obligate parasites
- (D) Carnivorous predators

Q36. BIO

Which of the following viral pathogens is transmitted parenterally through contaminated blood products and shared hypodermic needles?

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

Q37. BIO

The light-independent phase (Calvin-Benson cycle) of photosynthesis is directly responsible for the:

- (A) Formation of energy-rich carbohydrates
- (B) Photolytic splitting of water
- (C) Generation of ATP via ATP synthase
- (D) Enzymatic production of NADPH

Q38. BIO

In the porphyrin head of a chlorophyll molecule, light absorption promotes electrons to higher energy orbitals within the cloud surrounding:

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

Q39. BIO

Which of the following proteins possesses an insoluble, elongated fibrous structure providing mechanical tensile strength?

- (A) Pepsin
- (B) Collagen
- (C) Haemoglobin
- (D) Insulin

Q40. BIO

Which physiological role is characteristic of lipids (subcutaneous adipose tissue) rather than proteins?

- (A) Providing structural integrity to the cellular cytoskeleton
- (B) Catalysing cellular biochemical reactions
- (C) Facilitating transmembrane carrier transport
- (D) Providing thermal insulation against heat loss

Q41. BIO

A lipid molecule composed of three fatty acid hydrocarbon chains esterified to a single glycerol backbone is designated a:

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

Q42. BIO

Which covalent bond present in abundance within carbohydrates and lipids serves as the primary source of chemical energy during cellular oxidation?

- (A) C=O
- (B) C-H
- (C) C-N
- (D) O-H

Q43. BIO

Water acts as an efficient thermal buffer in biological systems because of which specific physical property?

- (A) High molecular polarity
- (B) Non-polar intermolecular bonding
- (C) High specific heat capacity
- (D) High boiling point relative to hydrocarbons

Q44. BIO

Which of the following macromolecular classes does NOT form a structural constituent of the fluid mosaic plasma membrane?

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

Q45. BIO

Among the major classes of carbohydrates, which group is characteristically the sweetest in taste?

- (A) Monosaccharides
- (B) Disaccharides
- (C) Oligosaccharides
- (D) Polysaccharides

Q46. BIO

Which organelle is referred to as the 'suicidal bag' of the animal cell due to its high concentration of acid hydrolases?

- (A) Peroxisome
- (B) Lysosome
- (C) Glyoxysome
- (D) Phagosome

Q47. BIO

The rigid structural cell wall of fungi is chemically composed of:

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

Q48. BIO

Which organelle in neurons is responsible for sorting, modifying, and packaging neurosecretory products into synaptic vesicles?

- (A) Glyoxysome
- (B) Peroxisome
- (C) Golgi apparatus
- (D) Rough endoplasmic reticulum

Q49. BIO

The inner membrane of a mitochondrion projects into the internal matrix cavity via deep, shelf-like folds called:

- (A) Cisternae
- (B) Cristae
- (C) Chromatin
- (D) Granal stacks

Q50. BIO

In cellular signal transduction pathways, the membrane-associated protein adenyl cyclase functions biochemically as a(n):

- (A) Ligand-gated channel
- (B) Transmembrane carrier protein
- (C) Enzyme
- (D) Secondary messenger

Q51. BIO

Glycogen granules and lipid droplets stored within the cytoplasm are classified as:

- (A) Cell organelles
- (B) Cell inclusions
- (C) Cytoplasmic matrix
- (D) Non-membranous organelles

Q52. BIO

Acquired immunity developed through administration of a vaccine containing attenuated or inactivated pathogens is an example of:

- (A) Natural passive immunity
- (B) Natural active immunity
- (C) Artificial active immunity
- (D) Artificial passive immunity

Q53. BIO

The human lymphatic system comprises all of the following structures EXCEPT:

- (A) Lymphoid masses
- (B) Lymphatic vessels
- (C) Spleen
- (D) Lungs

Q54. BIO

The unique structural macromolecular polymer forming the rigid framework of eubacterial cell walls is:

- (A) Polysaccharide
- (B) Globular protein
- (C) Peptidoglycan (murein)
- (D) Cholesterol

Q55. BIO

The horizontal transfer of genetic material from one bacterium to another mediated by a bacteriophage vector is termed:

- (A) Conjugation
- (B) Transformation
- (C) Transduction
- (D) Transposition

Q56. BIO

All of the following are physical methods used to control and destroy bacterial populations EXCEPT:

- (A) Autoclave sterilization
- (B) Boiling
- (C) Ionizing radiation
- (D) Antiseptics

Q57. BIO

Which of the following interventions stimulates the human immune system to develop specific, long-lasting protective antibodies against pathogens?

- (A) Radiotherapy
- (B) Chemotherapy
- (C) Vaccination
- (D) Broad-spectrum antibiotics

Q58. BIO

Following fertilization in the ampulla of the fallopian tube, the developing blastocyst takes approximately how long to traverse the tube and reach the uterine cavity?

- (A) 10 to 12 days
- (B) 3 to 6 days
- (C) 12 to 15 days
- (D) 18 to 21 days

Q59. BIO

Optimal human spermatogenesis within the seminiferous tubules occurs at a scrotal temperature of approximately:

- (A) 37 °C
- (B) 30 °C
- (C) 32 °C
- (D) 35 °C

Q60. BIO

In human females, follicle-stimulating hormone (FSH) secreted by the anterior pituitary directly stimulates:

- (A) Primary follicle development and oocyte maturation
- (B) Ovulation of the secondary oocyte
- (C) Embryo implantation into the endometrium
- (D) Onset of menstruation

Q61. BIO

Interstitial cells of Leydig situated between the seminiferous tubules of the testes are responsible for the production of:

- (A) Testosterone
- (B) Follicle-stimulating hormone
- (C) Spermatozoa
- (D) Inhibin

Q62. BIO

During skeletal muscle contraction, the resetting and detachment of actin-myosin cross-bridges is driven by which biochemical process?

- (A) ATP is oxidized
- (B) ATP is reduced
- (C) ATP is hydrolyzed
- (D) ATP is synthesized

Q63. BIO

The clinical condition characterized by chronic inflammation and degenerative breakdown of articular joint cartilage is:

- (A) Osteoarthritis
- (B) Osteoporosis
- (C) Arteriosclerosis
- (D) Osteosclerosis

Q64. BIO

Tetany, characterized by involuntary spastic muscle contractions, is precipitated by which electrolyte disturbance in the blood?

- (A) Hypocalcaemia (Low Ca^{2+})
- (B) Hypercalcaemia (High Ca^{2+})
- (C) Hypomagnesaemia (Low Mg^{2+})
- (D) Hypermagnesaemia (High Mg^{2+})

Q65. BIO

What is the primary physiological function of myoglobin in skeletal and cardiac muscle fibers?

- (A) Storing oxygen for periods of intense metabolic demand
- (B) Storing carbon dioxide
- (C) Systemic transport of oxygen in the blood
- (D) Transporting carbon dioxide to the lungs

Q66. BIO

A freely movable joint where articulating bone ends are capped with hyaline articular cartilage and enclosed by a fibrous capsule containing lubricating fluid is a:

- (A) Cartilaginous joint
- (B) Synovial joint
- (C) Fibrous joint
- (D) Synarthrodial joint

Q67. BIO

Genes located close to each other on the same chromosome that tend to be co-inherited into gametes and violate Mendel's law of independent assortment are termed:

- (A) Linked genes
- (B) Dependent genes
- (C) Recombinant genes
- (D) Independent genes

Q68. BIO

Classical Mendelian monohybrid inheritance in garden peas is governed by which dominance relationship?

- (A) Complete dominance
- (B) Incomplete dominance
- (C) Co-dominance
- (D) Multiple allelic dominance

CHEM SECTION: CHEMISTRY

Questions 69 to 122 (54 MCQs)

Q69. CHEM

Solid crystalline iodine (I_2) forms which structural class of crystal lattice?

- (A) Molecular crystals
- (B) Ionic crystals
- (C) Covalent network crystals
- (D) Metallic crystals

Q70. CHEM

When two ice cubes are firmly pressed together, they fuse into a single ice cube primarily due to:

- (A) Permanent dipole-dipole attractions
- (B) Covalent bond formation
- (C) London dispersion forces
- (D) Hydrogen bonding (regelation)

Q71. CHEM

For the Haber synthesis reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + \text{Heat}$, which procedure continuously maximizes the yield of NH_3 ?

- (A) Increasing the reaction temperature
- (B) Decreasing total system pressure
- (C) Increasing the reaction vessel volume
- (D) Continuous withdrawal of ammonia after intervals

Q72. CHEM

A high operating pressure of approximately 200 atm is employed in the industrial Haber process to achieve:

- (A) Higher equilibrium yield of ammonia
- (B) Lower equilibrium yield of ammonia
- (C) Lower reaction rate
- (D) Lower equipment maintenance cost

Q73. CHEM

By which of the following operational factors is the chemical equilibrium state attained in the shortest time?

- (A) Increasing temperature
- (B) Increasing pressure
- (C) Increasing reactant concentration
- (D) Adding a suitable catalyst

Q74. CHEM

Which of the following is NOT a recognized laboratory or physiological application of a buffer solution?

- (A) Calibration of electro-analytical pH meters
- (B) Preservation of biological specimens and tissues
- (C) Maintenance of normal human blood pH
- (D) Directly predicting the unknown concentration of a solute

Q75. CHEM

Which of the following statements regarding the activated complex (transition state) is INCORRECT?

- (A) It is a high-energy species
- (B) It is a stable, isolable chemical species
- (C) It is an unstable, transient configuration
- (D) Potential energy reaches a maximum at this stage

Q76. CHEM

The unit of the rate constant (k) is identical to the unit of the rate of reaction for which order of reaction?

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

Q77. CHEM

If a reaction is first-order with respect to a reactant, the rate of reaction will change by what factor if the concentration of that reactant is doubled?

- (A) Doubled
- (B) Halved
- (C) Reduced to one-fourth
- (D) Quadrupled

Q78. CHEM

The mathematical formulation representing the First Law of Thermodynamics is:

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

Q79. CHEM

One thermochemical calorie (cal) is defined as being equivalent to exactly:

- (A) 4.184 kJ
- (B) 4.184 J
- (C) 0.4184 kJ/mol
- (D) 0.4184 kJ

Q80. CHEM

The total thermal energy or heat content of a thermodynamic system measured at constant pressure is termed:

- (A) Enthalpy
- (B) Internal energy
- (C) Heat capacity
- (D) Work done

Q81. CHEM

Which statement correctly defines the standard electrode potential (E°) of an element?

- (A) The electrode potential measured at room temperature and pressure using an arbitrary inert cathode
- (B) The potential generated when an element is in equilibrium with its 1 M ion solution at 298 K and 1 atm compared to a Standard Hydrogen Electrode
- (C) The chemical potential of a pure metal rod immersed in water relative to standard hydrogen gas
- (D) The potential difference measured when any two arbitrary galvanic half-cells are connected together

Q82. CHEM

The oxidation number assigned to any chemical element in its free, uncombined elemental state is always:

- (A) Negative
- (B) Positive
- (C) Zero
- (D) ± 1

Q83. CHEM

The branch of physical chemistry that investigates the interconversion of electrical energy and chemical energy is termed:

- (A) Electrochemistry
- (B) Thermochemistry
- (C) Stereochemistry
- (D) Biochemistry

Q84. CHEM

Which of the following hydrogen halide molecules exhibits the greatest difference in electronegativity across its covalent bond?

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

Q85. CHEM

First ionization energy decreases progressively down Group IIA because:

- (A) The shielding effect remains constant
- (B) The atomic radius remains constant
- (C) The effective nuclear charge increases rapidly
- (D) The atomic radius and shielding effect increase

Q86. CHEM

Both carbon atoms in an ethane molecule (C_2H_6) exhibit which type of orbital hybridization?

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

Q87. CHEM

The primary type of chemical bonding holding zinc atoms together in solid zinc metal is:

- (A) Ionic bonding
- (B) Covalent bonding
- (C) Coordinate covalent bonding
- (D) Metallic bonding

Q88. CHEM

Which of the following elements is classified as an intrinsic semiconductor?

- (A) Aluminium (Al)
- (B) Silicon (Si)
- (C) Phosphorus (P)
- (D) Magnesium (Mg)

Q89. CHEM

Which of the following periodic properties decreases progressively down Group IIA (alkaline earth metals)?

- (A) Atomic radius
- (B) Nuclear charge (atomic number)
- (C) Shielding effect
- (D) First ionization energy

Q90. CHEM

Which alkali metal forms both a normal oxide and a peroxide when burned in oxygen?

- (A) Sodium (Na)
- (B) Potassium (K)
- (C) Lithium (Li)
- (D) Caesium (Cs)

Q91. CHEM

Which first-row transition metal element does NOT exhibit variable oxidation states in its compounds?

- (A) Copper (Cu)
- (B) Scandium (Sc)
- (C) Zinc (Zn)
- (D) Chromium (Cr)

Q92. CHEM

In the first transition metal series (3d series), the cohesive binding energy increases progressively from left to right up to:

- (A) Group IIB
- (B) Group IVB
- (C) Group IIIB
- (D) Group VB / VIB

Q93. CHEM

Homocyclic (carbocyclic) organic compounds are subdivided into which two primary structural classes?

- (A) Alicyclic and aromatic compounds
- (B) Open chain and branched chain compounds
- (C) Heterocyclic and aromatic compounds
- (D) Saturated and unsaturated acyclic compounds

Q94. CHEM

The type of constitutional isomerism arising from the dynamic migration of a hydrogen atom (proton) accompanied by the shift of a double bond within the same molecule is called:

- (A) Chain isomerism
- (B) Metamerism
- (C) Tautomerism
- (D) Position isomerism

Q95. CHEM

In saturated alkanes, each carbon atom exhibits which hybridization state and geometry?

- (A) sp^3 with tetrahedral geometry
- (B) sp with linear geometry
- (C) sp^2 with trigonal planar geometry
- (D) dsp^2 with square planar geometry

Q96. CHEM

For the stoichiometric reaction $N_2 + 3H_2 \rightarrow 2NH_3$, how many moles of N_2 are required to produce 4.0 moles of NH_3 ?

- (A) 4.0 moles
- (B) 2.0 moles
- (C) 3.0 moles
- (D) 1.0 mole

Q97. CHEM

According to the reaction $4Al + 3O_2 \rightarrow 2Al_2O_3$, how many grams of O_2 are completely consumed by reacting with 27.0 g of aluminium metal?

- (A) 8.0 g
- (B) 16.0 g
- (C) 24.0 g
- (D) 32.0 g

Q98. CHEM

The principal quantum number, which designates the primary energy shell and relative distance of an electron from the nucleus, is denoted by the symbol:

- (A) m
- (B) n
- (C) s
- (D) l

Q99. CHEM

The geometric shape and angular momentum of an atomic orbital subshell are determined by which quantum number?

- (A) Principal quantum number (n)
- (B) Azimuthal quantum number (l)
- (C) Magnetic quantum number (m_l)
- (D) Spin quantum number (m_s)

Q100. CHEM

The rule stating that in degenerate orbitals, electrons enter singly with parallel spins before pairing occurs is:

- (A) Aufbau principle
- (B) $(n + l)$ rule
- (C) Hund's rule of maximum multiplicity
- (D) Pauli exclusion principle

Q101. CHEM

One mole of any chemical substance is defined as the quantity of matter that contains exactly the same number of elementary entities as there are carbon atoms in:

- (A) 1.008 g of hydrogen gas (H_2)
- (B) 16.00 g of oxygen gas (O_2)
- (C) 12.00 g of pure carbon-12 (^{12}C) isotope
- (D) 12.00 g of natural magnesium metal

Q102. CHEM

According to the Pauli exclusion principle, the maximum number of electrons that can occupy a single atomic orbital is:

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

Q103. CHEM

Atmospheric air is a homogeneous mixture of gases. The gaseous molecules do not settle toward the Earth under gravity primarily due to:

- (A) Differences in molar masses of component gases
- (B) The non-polar covalent nature of atmospheric gases
- (C) Suspension provided by atmospheric dust particles
- (D) Continuous rapid motion and elastic collisions of gas molecules

Q104. CHEM

According to the Kinetic Molecular Theory of gases, collisions between gas molecules involve:

- (A) No net change in total kinetic energy
- (B) No change in instantaneous molecular momentum
- (C) A small but permanent dissipation of thermal energy
- (D) A large loss of kinetic energy into potential energy

Q105. CHEM

According to Charles's law, the volume of an ideal gas theoretically reduces to zero at which temperature?

- (A) -12.00°C
- (B) 0.00°C
- (C) -273.15°C
- (D) -210.00°C

Q106. CHEM

The strongest individual hydrogen bond is formed between molecules of:

- (A) H_2S
- (B) HF
- (C) H_2O
- (D) NH_3

Q107. CHEM

Which of the following liquids possesses the highest surface tension at room temperature?

- (A) Benzene
- (B) Ethyl alcohol
- (C) Diethyl ether
- (D) Water

Q108. CHEM

Which of the following hydrocarbons has the highest normal boiling point?

- (A) C_4H_{10} (Butane)
- (B) C_6H_{14} (Hexane)
- (C) $\text{C}_{10}\text{H}_{22}$ (Decane)
- (D) C_3H_8 (Propane)

Q109. CHEM

Ice floats on the surface of liquid water primarily because:

- (A) The covalent O-H bond length is significantly larger in ice
- (B) Ice adopts a compact cubic close-packed metallic lattice
- (C) Intermolecular forces in ice are weaker than in liquid water
- (D) Its open hexagonal crystal structure contains empty cage-like spaces

Q110. CHEM

Which of the following aromatic hydrocarbons is resistant to oxidation by standard oxidizing agents (such as acidified KMnO_4)?

- (A) Benzene
- (B) Toluene
- (C) Ethylbenzene
- (D) o-Xylene

Q111. CHEM

The correct order of reactivity of hydrocarbons towards electrophilic addition reactions is:

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

Q112. CHEM

The reactivity order of halogen acids (hydrogen halides) towards cleavage and acidic strength is:

- (A) $\text{HF} > \text{HCl} > \text{HBr} > \text{HI}$
- (B) $\text{HBr} > \text{HCl} > \text{HI} > \text{HF}$
- (C) $\text{HCl} > \text{HBr} > \text{HI} > \text{HF}$
- (D) $\text{HI} > \text{HBr} > \text{HCl} > \text{HF}$

Q113. CHEM

Alkyl halides (haloalkanes) are formally considered the mono-halogen derivatives of:

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

Q114. CHEM

A Grignard reagent is synthesized by reacting an alkyl halide in dry ether with:

- (A) Calcium metal
- (B) Potassium metal
- (C) Sodium metal
- (D) Magnesium metal

Q115. CHEM

Phenol is readily susceptible to oxidation by oxidizing agents primarily because:

- (A) The hydroxyl group strongly activates the aromatic ring toward oxidation
- (B) The aromatic ring is deactivated toward electrophilic attack
- (C) The phenolic C-O bond is extremely weak and easily cleaved
- (D) Phenols are strong reducing agents that cannot form quinones

Q116. CHEM

Both aliphatic alcohols and aromatic phenols contain which characteristic functional group?

- (A) Hydroxyl group ($-\text{OH}$)
- (B) Carboxyl group ($-\text{COOH}$)
- (C) Methylene group ($-\text{CH}_2-$)
- (D) Formyl group ($-\text{CHO}$)

Q117. CHEM

Select the correct sequence of relative acidic strength among carboxylic acids, phenols, water, and alcohols:

- (A) Carboxylic acid > Water > Phenol > Alcohol
- (B) Carboxylic acid > Phenol > Water > Alcohol
- (C) Carboxylic acid > Alcohol > Phenol > Water
- (D) Carboxylic acid > Water > Alcohol > Phenol

Q118. CHEM

Carboxylic acids react with alcohols in the presence of an inorganic acid catalyst to form:

- (A) Esters
- (B) Aldehydes
- (C) Ketones
- (D) Alkyl halides

Q119. CHEM

Catalytic hydrogenation of aldehydes and ketones using molecular hydrogen over a nickel catalyst produces:

- (A) Alcohols
- (B) Carboxylic acids
- (C) Alkanes
- (D) Acid anhydrides

Q120. CHEM

When an aldehyde lacking α -hydrogens reacts with 50% concentrated NaOH, it undergoes self-oxidation-reduction via the:

- (A) 2,4-DNPH condensation reaction
- (B) Aldol condensation reaction
- (C) Clemmensen reduction
- (D) Cannizzaro reaction

Q121. CHEM

Based on biological function, the iodinated amino acid derivative thyroxine (T_4) is classified as a:

- (A) Hormonal regulator
- (B) Structural protein
- (C) Transport protein
- (D) Genetic protein

Q122. CHEM

An enzyme is a natural biological substance that:

- (A) Increases the rate of a chemical reaction
- (B) Decreases the rate of a chemical reaction
- (C) Has no effect on the rate of a chemical reaction
- (D) Completely prevents the chemical reaction from occurring

PHY SECTION: PHYSICS

Questions 123 to 176 (54 MCQs)

Q123. PHY

The SI derived unit of kinetic energy is identical to the unit of:

- (A) Mechanical work
- (B) Power per unit time
- (C) Time divided by power
- (D) Work per unit time

Q124. PHY

Which of the following forces provides the necessary centripetal force for an automobile negotiating an unbanked horizontal circular turn?

- (A) Vertical component of the automobile's weight
- (B) Horizontal component of the normal reaction force
- (C) Total downward gravitational force
- (D) Static friction between the tires and the road surface

Q125. PHY

How many radians are contained in a plane angle of exactly one degree (1°)?

- (A) 0.0174 rad
- (B) 0.174 rad
- (C) 1.745 rad
- (D) 0.00174 rad

Q126. PHY

What is the angular velocity of an electric motor shaft rotating at a steady speed of 400 revolutions per minute (rpm)?

- (A) 51.2 rad/s
- (B) 41.9 rad/s
- (C) 45.2 rad/s
- (D) 38.5 rad/s

Q127. PHY

For an object of mass m moving in a vertical circle of radius r on a light string, the tension at the topmost point at minimum critical speed is:

- (A) Zero
- (B) mg
- (C) $2mg$
- (D) $4mg$

Q128. PHY

The expression for centripetal force F_c in terms of mass m , radius r , and angular velocity ω is:

- (A) $F_c = mr\omega$
- (B) $F_c = mr\omega^2$
- (C) $F_c = mr\alpha^2$
- (D) $F_c = mr\alpha$

Q129. PHY

What is the angular speed in radians per hour of the Earth's daily rotation about its axis?

- (A) 2π
- (B) 4π
- (C) $\pi/6$
- (D) $\pi/12$

Q130. PHY

The wavelength (λ) of a progressive wave is defined as the:

- (A) Linear distance between two consecutive crests or troughs
- (B) Linear distance between two alternate crests
- (C) Linear distance between two alternate troughs
- (D) Total distance spanned by two crests and two troughs

Q131. PHY

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

- (A) Static pressure
- (B) Gas density
- (C) Temperature
- (D) Nature of the gaseous medium

Q132. PHY

The maximum displacement of vibrating particles of a medium from their equilibrium position is termed:

- (A) Frequency
- (B) Amplitude
- (C) Wavelength
- (D) Crest

Q133. PHY

Ultrasonic sound waves are characterized by frequencies exceeding the upper limit of human hearing, which is:

- (A) 20 Hz
- (B) 20 kHz
- (C) 200 kHz
- (D) 2000 kHz

Q134. PHY

The speed of sound in air increases for each 1°C rise in temperature above 0°C by approximately:

- (A) 0.61 m/s
- (B) 0.51 m/s
- (C) 0.41 m/s
- (D) 0.31 m/s

Q135. PHY

A continuous, regular, and rhythmic disturbance generated in a medium by the periodic vibration of a source produces:

- (A) Complex waves
- (B) Stationary waves
- (C) Electromagnetic waves
- (D) Periodic waves

Q136. PHY

A thermodynamic process in which the volume of the working substance remains strictly constant is called an:

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

Q137. PHY

The conditions for the application of Boyle's law ($PV = \text{constant}$) are satisfied during which thermodynamic process?

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

Q138. PHY

During an isothermal expansion of an ideal gas, its internal energy:

- (A) Decreases significantly
- (B) Increases proportionally
- (C) Becomes zero
- (D) Remains constant

Q139. PHY

The electric intensity and electric flux associated with symmetrical continuous charge distributions are calculated using:

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

Q140. PHY

The capacitance of a parallel plate capacitor does NOT depend on the:

- (A) Surface area of the plates
- (B) Permittivity of the dielectric medium
- (C) Separation distance between the plates
- (D) Thickness of the conductive plates

Q141. PHY

The SI unit of electric potential difference is the:

- (A) Volt
- (B) Coulomb
- (C) Watt
- (D) Electron-volt

Q142. PHY

Electric potential at a specific point in an electrostatic field is formally defined as the:

- (A) Work done per unit positive charge in bringing it from infinity to that point
- (B) Electrostatic force exerted per unit positive test charge
- (C) Electrical power consumed per unit charge
- (D) Total potential energy of the source charge distribution

Q143. PHY

The ohm-meter ($\Omega \cdot m$) is the derived SI unit of:

- (A) Electrical resistance
- (B) Electrical resistivity
- (C) Electrical conductance
- (D) Electrical conductivity

Q144. PHY

One electron-volt (1 eV) of energy is equivalent to exactly how many joules?

- (A) $1.602 \times 10^{-19} \text{ J}$
- (B) $16.02 \times 10^{-19} \text{ J}$
- (C) 1620 J
- (D) $162.0 \times 10^{-19} \text{ J}$

Q145. PHY

The electrical resistance of a uniform metallic wire of length L and uniform cross-sectional area A is inversely proportional to:

- (A) Length of the wire
- (B) Cross-sectional area of the wire
- (C) Operating temperature
- (D) Resistivity of the conductor

Q146. PHY

The commercial electrical billing unit kilowatt-hour ($kW \cdot h$) is a unit of:

- (A) Electrical energy
- (B) Electrical power
- (C) Linear momentum
- (D) Electrical current

Q147. PHY

The magnetic force exerted on a charged particle moving through a uniform magnetic field is maximized when the angle between its velocity vector and the magnetic field vector is:

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

Q148. PHY

When a charged particle enters a uniform magnetic field with its velocity oriented parallel to the field lines, it will:

- (A) Deflect toward the north
- (B) Deflect toward the south
- (C) Continue along a straight path with undeflected motion
- (D) Follow a circular helical trajectory

Q149. PHY

The SI unit of magnetic induction (magnetic flux density) is the tesla (T), which is defined as:

- (A) $\text{N} \cdot \text{A}^{-1} \cdot \text{m}^{-1}$
- (B) $\text{N} \cdot \text{m} \cdot \text{A}^{-1}$
- (C) $\text{N}^{-1} \cdot \text{m} \cdot \text{A}$
- (D) $\text{N} \cdot \text{m} \cdot \text{A}$

Q150. PHY

In an isolated mechanical system, two balls undergo an elastic collision. Which statement is physically valid regarding this collision?

- (A) Total kinetic energy before collision equals total kinetic energy after collision
- (B) Total linear momentum before collision is not equal to total momentum after collision
- (C) Total kinetic energy before collision is not equal to total kinetic energy after collision
- (D) Total linear momentum before collision equals kinetic energy after collision

Q151. PHY

The gradient (slope) of a velocity–time graph represents which physical quantity?

- (A) Total displacement
- (B) Applied net force
- (C) Instantaneous acceleration
- (D) Instantaneous speed

Q152. PHY

For a projectile launched with a given initial speed, the horizontal ranges are identical for which pair of launch angles?

- (A) 20° and 60°
- (B) 60° and 30°
- (C) 40° and 60°
- (D) 25° and 55°

Q153. PHY

Two automobiles travel along a straight highway in opposite directions with constant speeds of 70 km/h and 60 km/h. What is their relative speed with respect to each other?

- (A) 10 km/h
- (B) 130 km/h
- (C) 65 km/h
- (D) 5 km/h

Q154. PHY

Two bodies of equal mass m undergo a one-dimensional head-on elastic collision. Their velocities after the collision will be:

- (A) $v'_1 = 0, v'_2 = 0$
- (B) $v'_1 = v_2, v'_2 = 0$
- (C) $v'_1 = v_1, v'_2 = v_2$
- (D) $v'_1 = v_2, v'_2 = v_1$

Q155. PHY

The launch angle of a projectile for which its maximum height equals its horizontal range is approximately:

- (A) 86°
- (B) 46°
- (C) 66°
- (D) 76°

Q156. PHY

The slope of a distance–time graph can never be:

- (A) Positive
- (B) Negative
- (C) Zero
- (D) Constant

Q157. PHY

What are the horizontal and vertical velocity components of a projectile at the apex of its trajectory?

- (A) $v_x = 0, v_y = 0$
- (B) $v_x = 0, v_y = \text{constant}$
- (C) $v_x = \text{constant}, v_y = \text{constant}$
- (D) $v_x = \text{constant}, v_y = 0$

Q158. PHY

The conventional engineering unit of power in the British gravitational system is the:

- (A) Horsepower
- (B) Watt
- (C) Joule per second
- (D) Joule-second

Q159. PHY

Mechanical work done by a force is negative when the angle θ between the force vector and displacement vector is:

- (A) 0°
- (B) 45°
- (C) 60°
- (D) 180°

Q160. PHY

A power consumption rate of $1 \text{ N} \cdot \text{m} \cdot \text{s}^{-1}$ is equivalent to:

- (A) $1 \text{ kW} \cdot \text{h}$
- (B) $1 \text{ J} \cdot \text{s}$
- (C) 1 Watt
- (D) $1 \text{ J} \cdot \text{s}^{-2}$

Q161. PHY

In energy transformations involving motion against a frictional force f across a distance or height h , the work done against friction is given by:

- (A) $f + h$
- (B) $f - h$
- (C) fh
- (D) f/h

Q162. PHY

A car of mass 800 kg accelerates uniformly along a straight track from 20 m/s to 30 m/s. What is the total increase in its kinetic energy?

- (A) 2 J
- (B) 200 kJ
- (C) 200 J
- (D) 2 kJ

Q163. PHY

In Fleming's right-hand rule for induced electromotive force, the middle finger (second finger) points in the direction of the:

- (A) Applied mechanical force
- (B) External magnetic field
- (C) Induced electric current
- (D) Conductor acceleration

Q164. PHY

An alternating current electrical transformer operates on the principle of:

- (A) Lenz's law
- (B) Coulomb's electrostatic law
- (C) Mutual electromagnetic induction
- (D) Ampere's circuital law

Q165. PHY

While ideal transformers are 100% efficient, well-designed commercial power transformers typically operate with an efficiency of approximately:

- (A) 60%
- (B) 70%
- (C) 80%
- (D) 90%

Q166. PHY

Lenz's law of electromagnetic induction is a direct consequence of the law of conservation of:

- (A) Electric charge
- (B) Energy
- (C) Linear momentum
- (D) Mass

Q167. PHY

A circuit that converts only one half of an alternating current input waveform into direct current is called a:

- (A) Full-wave rectifier
- (B) Signal amplifier
- (C) Half-wave rectifier
- (D) Voltage inverter

Q168. PHY

The maximum theoretical efficiency of a full-wave rectifier is approximately how many times that of a half-wave rectifier?

- (A) Four times
- (B) The same
- (C) Sixteen times
- (D) Double (two times)

Q169. PHY

Which electronic semiconductor component conducts current primarily in one direction and is used as a rectifier?

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

Q170. PHY

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

- (A) Higher frequency and shorter wavelength
- (B) Lower frequency and shorter wavelength
- (C) Lower frequency and longer wavelength
- (D) Higher frequency and longer wavelength

Q171. PHY

Which photons in the visible spectrum carry the greatest quantum energy?

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

Q172. PHY

In the hydrogen atomic emission spectrum, which spectral line series lies entirely in the ultraviolet region?

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

Q173. PHY

Which of the following characteristic X-ray transitions emits a photon with the longest wavelength?

- (A) K_{α}
- (B) K_{β}
- (C) K_{γ}
- (D) M series (such as M_{α})

Q174. PHY

The radioactive half-life of Iodine-131 (^{131}I), used clinically in thyroid radiometry, is approximately:

- (A) 10 days
- (B) 8 days
- (C) 45 days
- (D) 60 days

Q175. PHY

The half-life of Carbon-14 is 5,730 years. What fraction of the original radioactive Carbon-14 sample remains undecayed after 22,920 years?

- (A) $\frac{1}{32}$
- (B) $\frac{1}{16}$
- (C) $\frac{1}{64}$
- (D) $\frac{1}{8}$

Q176. PHY

Radiation-induced injuries such as skin burns, epilation (hair loss), and a drop in white blood cell counts in an exposed individual are classified as:

- (A) Somatic effects
- (B) Genetic effects
- (C) Metabolic effects
- (D) Teratogenic effects

ENG SECTION: ENGLISH

Questions 177 to 194 (18 MCQs)

Q177. ENGThe word **RITUAL** most nearly means:

- (A) Original
- (B) Religion
- (C) Routine
- (D) Custom

Q178. ENG

Choose the option with the correct spelling:

- (A) Renaissance
- (B) Renaissance
- (C) Renaissance
- (D) Reniassance

Q179. ENG

Choose the option with the correct spelling:

- (A) Expedient
- (B) Expedient
- (C) Expedient
- (D) Expediant

Q180. ENG

Choose the option with the correct spelling:

- (A) Defficiency
- (B) Daficiency
- (C) Deficiency
- (D) Defecency

Q181. ENG

Fill in the blank with the appropriate preposition:

Finally, the accused was found guilty _____ his crime.

- (A) From
- (B) Of
- (C) For
- (D) To

Q182. ENG

Select the word that best completes the sentence:

The hundreds of years old palace could not withstand the _____ of heavy rain.

- (A) Aftermath
- (B) Havoc
- (C) Annoyance
- (D) Massacre

Q183. ENG

Select the most appropriate verb to fill in the blank:

He began to _____ the heap of corns very carefully.

- (A) Assess
- (B) Inspect
- (C) Analyze
- (D) Evaluate

Q184. ENG

Classify the following sentence according to its grammatical mood and function:

How cold the night is!

- (A) Interrogative sentence
- (B) Declarative sentence
- (C) Exclamatory sentence
- (D) Imperative sentence

Q185. ENG

Identify the version of the sentence that contains correct punctuation, spelling, and clause structure:

- (A) Tennis gives you plenty of exercise, it develops quickness of eye, and calls your brains, your thinking power intoo action.
- (B) Tennis gives you plenti off exercise; it develops quickness of eye, limb your brain; your thinking power over action.
- (C) Tennis gives you plenty of exercise; it develops quickness of eye, limbupon your brane, your thinking power over the action.
- (D) Tennis gives you plenty of exercise; it develops quickness of eye and calls your brain, your thinking power into action.

Q186. ENG

Complete the cleft sentence with the grammatically correct verb form:

It _____ good players who bring good name to a country.

- (A) Was
- (B) Were
- (C) Is
- (D) Are

Q187. ENG

Choose the grammatically correct modal auxiliary verb to fill in the blank:

I don't think I _____ be able to go.

- (A) Can
- (B) Should
- (C) Shall
- (D) Must

Q188. ENG

Fill in the blank with the appropriate verb form:

Ethics _____ important for a peaceful and loving society.

- (A) Have
- (B) Has
- (C) Are
- (D) Is

Q189. ENG

Select the correct verb phrase to complete the sentence:

Engineers _____ working on a new project for the last three days.

- (A) Are
- (B) Has been
- (C) Have been
- (D) Ought to be

Q190. ENGThe word **CREDENTIALS** most nearly refers to:

- (A) Trust
- (B) Qualifications
- (C) Financial credits
- (D) Personal beliefs

Q191. ENG

Choose the option with correct punctuation, spelling, and conjunction usage:

- (A) The wind blew, the rain fell, and the lightning flashed.
- (B) The wind blue the rain fell, and the lightning flashed.
- (C) The wind blew the rain fell and the lightening flashed.
- (D) The wind blew, the rain fell; and the lightening flashed.

Q192. ENG

Identify the option that correctly renders the traditional English proverb:

- (A) Time, tide wait for no men.
- (B) Time and tide wait for no man.
- (C) The time and the tide weight for no man.
- (D) Time tide, wait over know man.

Q193. ENG

Select the appropriate phrasal verb to complete the sentence:

Negotiations between the two sides have _____.

- (A) Broken off
- (B) Broken down
- (C) Broken up
- (D) Broken in

Q194. ENG

Choose the sentence that is grammatically correct:

- (A) Your voice was recognized by me at once.
- (B) All her boats has been lost in the storm.
- (C) A committee of five were appointed.
- (D) The crowd were very big.

LOGIC SECTION: LOGICAL REASONING

Questions 195 to 200 (6 MCQs)

Q195. LOGIC

Read the passage and assess the statements below based solely on the provided text:

'The Early Medieval period (642–1219 CE) witnessed the spread of Islam in the region now known as Pakistan. During this period, Sufi missionaries played a pivotal role in converting a majority of the regional Buddhist and Hindu population to Islam.'

Statements:

- I. Islam was spread in the Pakistan region during the Early Medieval period.
- II. Sufi missionaries converted a large number of regional people to Islam during this time.
- III. Sufi missionaries were the sole cause of Pakistan becoming an Islamic republic.

Which statements are logically supported by the passage?

- (A) Only Statement I is supported
- (B) Statements I and II are supported
- (C) Statements I, II, and III are all supported
- (D) Statements I and III are supported

Q196. LOGIC

Select the shape configuration that logically comes next in the cyclical rotating sequence:



- (A) • • • •
- (B) • • • •
- (C) • • • •
- (D) • • • •

Q197. LOGIC

Three whole numbers X , Y , and Z are all greater than 11 and less than 24 (integers from 12 to 23 inclusive). Given that:

- X is the smallest prime number in this range,
- Y is the largest number divisible by 3 in this range,
- Z is the smallest number divisible by 11 in this range,

What are the values of X , Y , and Z ?

- (A) $X = 13$, $Y = 24$, $Z = 11$
- (B) $X = 13$, $Y = 21$, $Z = 22$
- (C) $X = 11$, $Y = 21$, $Z = 11$
- (D) $X = 11$, $Y = 24$, $Z = 22$

Q198. LOGIC

Read the two statements and choose the correct option describing their causal relationship:

Statement I: The government has significantly increased taxes on all businesses in Pakistan.

Statement II: Many small businesses will have to close their operations in Pakistan.

- (A) Statement I is the 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

Q199. LOGIC

Read the statement and determine which suggested course of action logically follows:

Statement: 'My laptop's battery is low and needs to be charged.'

Courses of Action:

- I. Stop using the laptop immediately to conserve power until it can be connected to a charger.
- II. Purchase a new battery and replace the old one each time it runs low.

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

Q200. LOGIC

Given the following categorical premises:

- All hammers are tools.
- Some tools are useless things.
- All useless things are trash.

Which of the following conclusions is NECESSARILY TRUE?

- (A) Conclusions I and III
- (B) Conclusions I and II
- (C) Conclusions II and III
- (D) Conclusion II only

OFFICIAL VERIFIED ANSWER KEY

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

SUBJECT-WISE PERFORMANCE BREAKDOWN

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

PMDC PROVINCIAL MERIT FORMULA

Official Weightage Law:

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

Estimated Provincial Merit Aggregate: ----- %

PROPOLIS COGNITIVE ERROR AUTOPSIES

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

Question #1 Key: (B)

BIOLOGY
04. Bioenergetics

Each granum in a chloroplast typically consists of how many thylakoids?

CORE CONCEPT & DERIVATION

Inside chloroplasts, the thylakoid membrane system forms disc-shaped structures stacked into functional photosynthetic units known as grana.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- According to the Federal Board biology textbook, each granum is composed of approximately 25 to 50 flattened, disc-shaped thylakoids stacked on top of one another like coins.
- This layered arrangement provides an extensive surface area for embedding chlorophyll pigments and electron transport complexes.

Why other options are incorrect:

- **Option A:** 40 to 60 is an incorrect range not supported by the Federal curriculum.
- **Option C:** 50 to 70 exceeds the average textbook value for typical granal stacks.
- **Option D:** 100 to 200 is far too high for an individual granum disc stack.

Question #2 Key: (D)

BIOLOGY
01. Cell

The specialized terminal ends of eukaryotic chromosomes are called:

CORE CONCEPT & DERIVATION

The physical ends of linear eukaryotic chromosomes contain repetitive non-coding DNA sequences that prevent chromosomal degradation and end-to-end fusion.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Telomeres consist of tandem repetitive hexanucleotide sequences (such as TTAGGG in vertebrates) capping chromosome ends.
- They safeguard genomic stability during successive rounds of DNA replication and prevent activation of DNA damage repair pathways.

Why other options are incorrect:

- **Option A:** Satellites are chromosomal segments located distal to secondary constrictions.
- **Option B:** Kinetochore are protein complexes assembled at centromeres where spindle fibers attach.
- **Option C:** Nucleolar organizer regions contain genes transcribing ribosomal RNA.

Question #3 Key: (B)BIOLOGY
01. Cell

Which cellular organelle is markedly more abundant in secretory cells compared to non-secretory...

CORE CONCEPT & DERIVATION

The Golgi apparatus functions as the central packaging, sorting, and chemical processing hub for proteins synthesized for secretion.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Cells specialized for exocrine or endocrine secretion (such as pancreatic acinar cells or plasma cells) require massive protein packaging machinery.
- Consequently, these cells possess an exceptionally well-developed and abundant Golgi complex to form secretory vesicles.

Why other options are incorrect:

- **Option A:** Lysosomes participate in intracellular digestion and autolysis rather than export of secretory products.
- **Option C:** Central vacuoles are prominent in mature plant cells for turgor and storage, not in animal secretory cells.
- **Option D:** Centrioles organize the mitotic spindle during cell division and do not participate in secretory export.

Question #4 Key: (C)BIOLOGY
01. Cell

Which nuclear structure disassembles and disappears during the early stages of cell division?

CORE CONCEPT & DERIVATION

During prophase of mitosis, specific non-membrane-bound nuclear structures disassemble as chromatin condenses into distinct chromosomes.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The nucleolus is the site of ribosomal RNA synthesis and ribosome subunit assembly.
- During prophase, transcription halts and the nucleolus disperses, disappearing entirely from view until it reforms in telophase.

Why other options are incorrect:

- **Option A:** Vacuoles remain present in the cytoplasm and do not disperse as a defined nuclear division marker.
- **Option B:** Lysosomes persist in the cytoplasm throughout cell division.
- **Option D:** The endoplasmic reticulum undergoes fragmentation into vesicles but is not a non-membrane nuclear structure characterized specifically by disappearance alongside the nucleolus.

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

The enzyme ATP synthase complex is embedded within the membrane of which organelle?

CORE CONCEPT & DERIVATION

ATP synthase utilizes a proton motive force established across an energy-transducing membrane to synthesize ATP from ADP and inorganic phosphate.

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

- In eukaryotic animal cells, ATP synthase (F_0F_1 complex) is localized exclusively within the inner mitochondrial membrane (cristae).
- Protons accumulated in the intermembrane space flow through the F_0 channel into the matrix, driving the catalytic rotary synthesis of ATP.

Why other options are incorrect:

- Option A:** The nuclear envelope does not maintain a chemiosmotic proton gradient and lacks ATP synthase.
- Option C:** Lysosomal membranes contain V-type H^+ -ATPases that consume ATP to pump protons inward, not synthesize ATP.
- Option D:** Vacuolar tonoplasts use ATP-driven proton pumps rather than F_0F_1 ATP synthases.

Question #6 Key: (B)BIOLOGY
01. Cell

Intracellular digestion of foreign particles and cellular debris is executed by which organelle...

CORE CONCEPT & DERIVATION

Lysosomes are single-membrane vesicles containing diverse acid hydrolases responsible for heterophagy, autophagy, and defense against engulfed pathogens.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Lysosomes fuse with phagosomes or endosomes to form secondary lysosomes.
- Hydrolytic enzymes operating at an optimum pH near 4.5 to 5.0 break down incoming macromolecules into reusable micro-nutrients.

Why other options are incorrect:

- Option A:** Vacuoles mainly store water, solutes, and waste products rather than executing primary catabolic digestion in animal cells.
- Option C:** The Golgi apparatus modifies and routes proteins rather than degrading macromolecules.
- Option D:** Ribosomes translate messenger RNA into polypeptide chains and have no hydrolytic capability.

Question #7 Key: (D)BIOLOGY
12. Nervous Coordination

Which of the following axons conducts an action potential with the highest velocity?

CORE CONCEPT & DERIVATION

Conduction velocity along a neuronal axon is directly proportional to axon diameter and is substantially increased by myelin insulation via saltatory conduction.

Formula / Rule / Reaction:

$$\text{Velocity} \propto \text{Axon Diameter} \quad \text{and} \quad \text{Velocity}_{\text{myelinated}} \gg \text{Velocity}_{\text{unmyelinated}}$$

Solution:

- A wider axon diameter (2 mm compared to 1 mm) reduces internal cytoplasmic resistance to longitudinal current flow.
- The presence of a myelin sheath prevents charge leakage and forces depolarization to jump rapidly between nodes of Ranvier.
- Combining the largest diameter with myelination yields the maximal conduction speed.

Why other options are incorrect:

- **Option A:** Unmyelinated 1 mm neurons have high internal resistance and continuous, slow conduction.
- **Option B:** While myelinated, a 1 mm diameter has higher internal longitudinal resistance than a 2 mm axon.
- **Option C:** A 2 mm unmyelinated neuron lacks saltatory conduction, leading to significantly slower propagation than its myelinated counterpart.

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

Chemically, vasopressin (antidiuretic hormone) is classified as a:

CORE CONCEPT & DERIVATION

Hormones are classified biochemically into steroids, peptide or protein derivatives, and amino acid or amine derivatives.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Vasopressin (ADH) is a nonapeptide consisting of a sequence of nine amino acids with an intramolecular disulfide bond.
- It is synthesized in the supraoptic and paraventricular nuclei of the hypothalamus and stored in the posterior pituitary gland.

Why other options are incorrect:

- **Option A:** Steroid hormones (such as aldosterone and cortisol) are derived from cholesterol.
- **Option B:** Catecholamines (such as epinephrine and norepinephrine) are tyrosine derivatives.
- **Option D:** Glycoproteins (such as TSH and FSH) are large proteins conjugated with carbohydrate moieties.

Question #9 Key: (D)BIOLOGY
12. Nervous Coordination

Which physiological process is NOT under the direct control of the hypothalamus?

CORE CONCEPT & DERIVATION

The hypothalamus is the primary visceral and autonomic homeostatic center of the brain, while higher cognitive functions are managed by the limbic system and neocortex.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The hypothalamus regulates body temperature, hunger, thirst, blood pressure, circadian sleep patterns, and fluid osmolarity.
- Long-term memory formation, consolidation, and storage are functions executed primarily by the hippocampus and the cerebral cortex.

Why other options are incorrect:

- **Option A:** Hunger is directly controlled by the lateral and ventromedial nuclei of the hypothalamus.
- **Option B:** Sleep-wake cycles are coordinated by the suprachiasmatic nucleus of the hypothalamus.
- **Option C:** Water balance is governed by hypothalamic osmoreceptors regulating ADH release.

Question #10 Key: (A)BIOLOGY
13. Chemical Coordination

Which hormone is stored and secreted by the posterior lobe of the pituitary gland?

CORE CONCEPT & DERIVATION

The neurohypophysis (posterior pituitary) does not synthesize hormones; it stores and releases neurohormones transported down axons from the hypothalamus.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The posterior pituitary stores and secretes two neurohormones: oxytocin and antidiuretic hormone (vasopressin).
- Oxytocin stimulates uterine contractions during parturition and milk ejection during lactation.

Why other options are incorrect:

- **Option B:** Thyroid-stimulating hormone (TSH) is synthesized and secreted by the anterior pituitary (adenohypophysis).
- **Option C:** Adrenocorticotrophic hormone (ACTH) is an anterior pituitary hormone.
- **Option D:** Follicle-stimulating hormone (FSH) is an anterior pituitary gonadotropin.

Question #11 Key: (B)BIOLOGY
12. Nervous Coordination

In the nervous system, action potentials are propagated across a chemical synapse via molecules...

CORE CONCEPT & DERIVATION

Chemical synaptic transmission relies on the exocytosis of specialized chemical messengers that diffuse across the synaptic cleft to bind postsynaptic receptors.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Arrival of an action potential triggers calcium influx into the presynaptic terminal.
- This promotes exocytosis of neurotransmitters (such as acetylcholine, dopamine, or GABA) into the synaptic cleft.

Why other options are incorrect:

- **Option A:** Communicator is a non-standard, generic term with no physiological definition.
- **Option C:** A nerve impulse is the wave of electrical depolarization along a single axon, not the chemical messenger molecule.
- **Option D:** Nociceptors are sensory nerve receptors specialized for detecting noxious, painful stimuli.

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

The microscopic functional junction between two neurons is termed a:

CORE CONCEPT & DERIVATION

Communication between successive excitable cells occurs across a specialized intercellular boundary called a synapse.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- A synapse comprises the presynaptic terminal, the narrow extracellular synaptic cleft (approximately 20 nm wide), and the postsynaptic membrane.
- It ensures unidirectional transmission of neural signals throughout the nervous system.

Why other options are incorrect:

- **Option A:** Synapsis is the pairing of homologous chromosomes during prophase I of meiosis.
- **Option C:** Collapse refers to structural failure and has no relevance to neuroanatomy.
- **Option D:** The synaptic knob is solely the terminal swelling of the presynaptic axon branch, not the entire junction.

Question #13 Key: (D)BIOLOGY
12. Nervous Coordination

In a somatic spinal reflex arc, the cell bodies of sensory afferent neurons are situated within...

CORE CONCEPT & DERIVATION

Sensory inputs from peripheral receptors enter the spinal cord dorsally, whereas motor signals exit ventrally (the Bell-Magendie law).

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Sensory neurons are pseudounipolar cells whose soma resides outside the central nervous system within the dorsal root ganglion.
- Their peripheral processes connect to sensory receptors, while central processes enter the dorsal horn of the spinal cord.

Why other options are incorrect:

- **Option A:** Ventral roots do not possess sensory ganglia; they carry motor efferent fibers.
- **Option B:** The grey matter of the spinal cord contains cell bodies of motor neurons and interneurons, not primary somatic sensory neurons.
- **Option C:** White matter contains myelinated axon tracts, devoid of neuronal cell bodies.

Question #14 Key: (A)BIOLOGY
12. Nervous Coordination

Basic emotional drives including feelings of love, anger, fear, and hate are primarily processed...

CORE CONCEPT & DERIVATION

The limbic system comprises interconnected subcortical structures responsible for emotional processing, motivation, and memory.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The amygdala is an almond-shaped nucleus within the temporal lobe essential for evaluating emotional valence.
- It plays the central role in processing intense emotional responses such as aggression, fear, affection, and social interactions.

Why other options are incorrect:

- **Option B:** The hippocampus is primarily involved in spatial navigation and memory consolidation.
- **Option C:** The thalamus acts as a sensory relay station for all incoming sensory information except olfaction.
- **Option D:** The hypothalamus executes visceral autonomic regulation and endocrine drive rather than generating emotional feelings.

Question #15 Key: (D)BIOLOGY
01. Cell

Which of the following statements correctly characterizes Amoeba?

CORE CONCEPT & DERIVATION

Amoeba belongs to the protozoan group Sarcodina (Amoebozoa), characterized by dynamic cytoplasmic streaming.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Amoeboid movement occurs through the projection of blunt cytoplasmic extensions termed pseudopodia (lobopodia).
- This streaming allows both locomotion and phagocytic engulfment of nutrients.

Why other options are incorrect:

- **Option A:** Flagellar motility is characteristic of Flagellates (Mastigophora), not sarcodines.
- **Option B:** Amoebae are strictly unicellular eukaryotic organisms.
- **Option C:** Several amoebae are pathogenic to humans, such as *Entamoeba histolytica* which causes amoebic dysentery.

Question #16 Key: (D)BIOLOGY
10. Homeostasis

Negative feedback homeostatic mechanisms for endothermic thermoregulation are characteristic of...

CORE CONCEPT & DERIVATION

Endothermy requires advanced physiological negative feedback loops that continuously adjust internal metabolic heat production and dissipation.

Formula / Rule / Reaction:

Stimulus (Temperature Deviation) → Hypothalamic Center → Effector Response → Correction

Solution:

- Mammals maintain a constant internal core body temperature through negative feedback coordinated by hypothalamic thermosensors.
- Deviations trigger physiological responses like vasoconstriction, sweating, shivering, or non-shivering thermogenesis to return core temperature to 37 °C.

Why other options are incorrect:

- **Option A:** Fish are ectotherms whose body temperature conforms passively to the surrounding aquatic environment.
- **Option B:** Amphibians are poikilothermic ectotherms lacking autonomic metabolic temperature regulation.
- **Option C:** Reptiles are ectotherms relying on behavioral adaptations rather than autonomic physiological negative feedback for warmth.

Question #17 Key: (A)BIOLOGY
03. Enzymes

The catalytic activity of an enzyme molecule is confined to a specialized localized region term...

CORE CONCEPT & DERIVATION

Enzymes are globular catalytic proteins whose substrate specificity and catalysis depend on a precise three-dimensional cleft.

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

- The active site consists of a few specific amino acid residues organized into a binding site and a catalytic site.
- Substrates bind via complementary non-covalent bonds, where catalytic residues lower the activation energy of the reaction.

Why other options are incorrect:

- **Option B:** Passive site is an unscientific distractor without biochemical definition.
- **Option C:** An allosteric site is a distinct non-catalytic site where effector molecules bind to modulate enzyme conformation.
- **Option D:** Regulatory site is synonymous with an allosteric site and does not execute primary chemical catalysis of the substrate.

Question #18 Key: (D)BIOLOGY
03. Enzymes

The proteolytic enzyme trypsin exhibits maximum enzymatic activity at approximately which pH?

CORE CONCEPT & DERIVATION

Every enzyme has an optimum pH at which its tertiary structure and active site ionization state yield maximal catalytic turnover.

Formula / Rule / Reaction:

$$\text{Optimum pH for Trypsin} \approx 7.8 - 8.2$$

Solution:

- Trypsin is secreted as trypsinogen by the pancreas and functions in the alkaline environment of the duodenum.
- Pancreatic bicarbonate neutralizes acidic gastric chyme, raising duodenal pH to approximately 8, matching trypsin's optimum.

Why other options are incorrect:

- **Option A:** pH 2 is the highly acidic optimum for gastric pepsin; trypsin completely denatures at this pH.
- **Option B:** pH 4 is too acidic for trypsin to maintain catalytic ionization.
- **Option C:** pH 6 is slightly acidic, below the optimal alkaline range of pancreatic proteases.

Question #20 Key: (B)BIOLOGY
03. Enzymes

Enzymes accelerate the rate of biochemical reactions primarily by lowering the:

CORE CONCEPT & DERIVATION

Catalysts do not alter the overall free energy change (ΔG) of a reaction; they stabilize the transition state to decrease the energy input required for activation.

Formula / Rule / Reaction:

$$\Delta G_{\text{catalyzed}}^{\ddagger} < \Delta G_{\text{uncatalyzed}}^{\ddagger}$$

Solution:

- Activation energy (E_a) is the minimum kinetic energy reactant molecules must possess to undergo chemical transformation.
- By orienting substrates and straining bonds, enzymes provide an alternative reaction pathway with a lower E_a .

Why other options are incorrect:

- **Option A:** Enzymes do not decrease reactant kinetic energy; kinetic energy is determined by temperature.
- **Option C:** Enthalpy change (ΔH) and net energy release are thermodynamic parameters that remain unchanged.
- **Option D:** The free energy of reactants and products is independent of enzyme activity.

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

Most enzymes operating within the human body display an optimum catalytic temperature near:

CORE CONCEPT & DERIVATION

Enzyme velocity increases with temperature until thermal denaturation disrupts non-covalent bonding of the active site.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- In humans, normal physiological core body temperature is 37 °C, and most human enzymes have an optimum between 37 °C and 40 °C.
- Among the given choices, 40 °C is the closest and most appropriate textbook value.

Why other options are incorrect:

- **Option A:** 30 °C yields lower molecular kinetic energy, resulting in sub-maximal reaction rates.
- **Option C:** 50 °C causes rapid unfolding and irreversible thermal denaturation of most human proteins.
- **Option D:** 20 °C represents ambient room temperature where human metabolic enzymes function sluggishly.

Question #21 Key: (A)BIOLOGY
03. Enzymes

In enzyme thermodynamics, the term 'maximum temperature' refers to the temperature threshold ab...

CORE CONCEPT & DERIVATION

Proteins maintain their tertiary globular conformation via weak interactions that are vulnerable to thermal disruption.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- As temperature rises above the physiological optimum, excessive atomic vibration ruptures hydrogen bonds, ionic bridges, and hydrophobic interactions.
- The maximum temperature represents the critical limit where thermal denaturation begins, causing irreversible loss of catalytic configuration.

Why other options are incorrect:

- **Option B:** Elevated temperatures disrupt folding and prevent renaturation.
- **Option C:** Highest catalytic efficiency occurs at the optimum temperature, which lies below the denaturation threshold.
- **Option D:** Thermal inactivation is typically irreversible, not a reactivation process.

Question #22 Key: (A)BIOLOGY
03. Enzymes

Which molecule decreases enzymatic reaction rates by competing directly with the substrate for ...

CORE CONCEPT & DERIVATION

Inhibition can occur reversibly at the catalytic center if an inhibitor mimics the substrate's spatial shape and charge distribution.

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

- A competitive inhibitor closely resembles the normal substrate and physically blocks substrate entry into the active site.
- This inhibition can be overcome by increasing substrate concentration.

Why other options are incorrect:

- **Option B:** Non-competitive inhibitors bind to an allosteric site away from the active site, altering the enzyme conformation without active-site competition.
- **Option C:** A coenzyme is a non-protein organic cofactor that assists catalytic activity rather than inhibiting it.
- **Option D:** Allosteric activators increase catalytic turnover by stabilizing the active conformation.

Question #23 Key: (D)BIOLOGY
16. Evolution

Who formulated the theory of evolution explaining the origin of species by means of natural sel...

CORE CONCEPT & DERIVATION

Natural selection is the mechanism by which individuals possessing heritable traits advantageous for survival reproduce more successfully, driving gradual evolutionary change.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Charles Darwin published *On the Origin of Species by Means of Natural Selection* in 1859.
- He proposed that differential reproductive success acting on natural phenotypic variation leads to adaptation and speciation over geological time.

Why other options are incorrect:

- Option A:** Lamarck proposed the incorrect hypothesis of inheritance of acquired characteristics and use/disuse.
- Option B:** Linnaeus established binomial nomenclature and modern taxonomic classification.
- Option C:** Hardy and Weinberg formulated the population genetics equilibrium principle regarding unchanging allele frequencies.

Question #24 Key: (A)BIOLOGY
16. Evolution

Geological strata reveal that the oldest known microfossils, dating back roughly 3.5 billion ye...

CORE CONCEPT & DERIVATION

The timeline of life on Earth began in the Precambrian Archean eon with single-celled anaerobic organisms preserved as microfossils and stromatolites.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Fossilized cyanobacteria-like filament structures found in Western Australian cherts date to approximately 3.5 billion years ago.
- These ancient specimens confirm that prokaryotes were the first living organisms on Earth.

Why other options are incorrect:

- Option B:** Amphibians emerged much later in the Devonian period (roughly 370 million years ago).
- Option C:** Reptiles arose during the Carboniferous period (roughly 315 million years ago).
- Option D:** The earliest jawless fishes appeared in the Ordovician/Silurian periods (around 500 million years ago).

Question #25 Key: (A)BIOLOGY
06. Digestion/Nutrition

What is the primary gastrointestinal action exerted by the peptide hormone cholecystokinin (CCK...

CORE CONCEPT & DERIVATION

Enteroendocrine I-cells of the duodenum secrete cholecystokinin in response to fatty acids and amino acids in incoming chyme.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- CCK travels through the bloodstream to bind smooth muscle receptors in the gallbladder wall.
- It causes rhythmic contraction of the gallbladder and relaxation of the sphincter of Oddi, expelling bile into the duodenum.

Why other options are incorrect:

- Option B:** Gastric mucus secretion is stimulated primarily by local prostaglandins and mechanical stimulation.
- Option C:** Hepatic bile secretion is primarily stimulated by secretin and bile salt reabsorption, not CCK.
- Option D:** Hydrochloric acid release is stimulated by gastrin, histamine, and acetylcholine.

Question #26 Key: (A)BIOLOGY
06. Digestion/Nutrition*Which of the following chemical entities is absent in human hepatic bile?***CORE CONCEPT & DERIVATION**

Bile is an exocrine hepatic secretion that aids in lipid digestion purely through physical detergent action rather than chemical enzymatic hydrolysis.

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

- Bile contains water, bile pigments (bilirubin), bile salts (sodium glycocholate and taurocholate), cholesterol, lecithin (phospholipids), and mucus.
- It contains no digestive enzymes whatsoever; lipid hydrolysis is executed separately by pancreatic and intestinal lipases.

Why other options are incorrect:

- **Option B:** Bile salts are the principal functional emulsifying agents present in bile.
- **Option C:** Mucus is secreted by gallbladder epithelial cells to line and protect bile ducts.
- **Option D:** Lecithin is a crucial phospholipid component in bile that keeps cholesterol solubilized in micelles.

Question #27 Key: (C)BIOLOGY
06. Digestion/Nutrition*The initial enzymatic cleavage of polypeptide chains occurs in which organ of the human digestive system?***CORE CONCEPT & DERIVATION**

Protein chemical digestion requires acidic denaturation and endopeptidase activity, both of which are initiated inside the gastric chamber.

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

- Dietary proteins encounter no proteolytic enzymes in the oral cavity or oesophagus.
- Upon entering the stomach, gastric juice provides hydrochloric acid (which denatures proteins) and pepsin (which cleaves peptide bonds).

Why other options are incorrect:

- **Option A:** Saliva contains salivary amylase and lingual lipase, which digest starches and fats, but lacks proteases.
- **Option B:** The oesophagus secretes only lubricating mucus and performs no chemical digestion.
- **Option D:** The small intestine continues and completes protein digestion via pancreatic enzymes, but it is not the first site of action.

Question #28 Key: (D)BIOLOGY
07. Circulation / Transport

At a normal resting heart rate of 75 beats per minute, the duration of a single cardiac cycle is...

CORE CONCEPT & DERIVATION

The cardiac cycle duration represents the reciprocal of heart rate, encompassing atrial systole, ventricular systole, and complete cardiac diastole.

Formula / Rule / Reaction:

$$\text{Cardiac Cycle Duration} = \frac{60 \text{ seconds}}{\text{Heart Rate (bpm)}} = \frac{60}{75} = 0.8 \text{ s}$$

Solution:

- A complete cycle lasts 0.8 seconds at a resting rate of 75 beats per minute.
- The timing is divided into atrial systole (0.1 s), ventricular systole (0.3 s), and complete ventricular diastole (0.4 s).

Why other options are incorrect:

- **Option A:** 0.6 s corresponds to an elevated tachycardic heart rate of 100 bpm.
- **Option B:** 0.4 s represents the duration of the ventricular diastole phase alone, not the entire cardiac cycle.
- **Option C:** 0.7 s corresponds to a heart rate of approximately 86 bpm.

Question #29 Key: (C)BIOLOGY
06. Digestion/Nutrition

Which hormone acts directly on the gastric mucosa to stimulate hydrochloric acid secretion from...

CORE CONCEPT & DERIVATION

Gastric acid secretion is coordinated by endocrine feedback mediated by peptide hormones responding to luminal peptide content.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Gastrin is produced by G-cells located in the pyloric antrum of the stomach.
- It circulates through the bloodstream to stimulate parietal (oxyntic) cells to secrete HCl and chief (zymogenic) cells to secrete pepsinogen.

Why other options are incorrect:

- **Option A:** Cholecystokinin stimulates pancreatic enzyme secretion and gallbladder contraction while inhibiting gastric motility.
- **Option B:** Secretin stimulates bicarbonate secretion from the pancreas and inhibits gastric acid production.
- **Option D:** Somatostatin acts as an inhibitory hormone that suppresses gastrin and hydrochloric acid release.

Question #30 Key: (B)BIOLOGY
07. Circulation/Transport

The route of water and mineral transport that traverses adjacent plant cells through cytoplasmic...

CORE CONCEPT & DERIVATION

Water travels through root tissues toward the vascular stele via three distinct physical routes: apoplastic, symplastic, and vacuolar.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The symplast represents the continuous, living system of interconnected protoplasts.
- Water enters the cytoplasm across a plasma membrane and moves between neighboring cells through plasmodesmata channels without crossing cell walls.

Why other options are incorrect:

- **Option A:** The apoplast pathway involves water movement through porous cell walls and extracellular intercellular spaces.
- **Option C:** The vacuolar pathway requires water to cross cell walls, plasma membranes, and vacuolar tonoplasts sequentially.
- **Option D:** Ascent of sap refers to the macro-transport of xylem fluid up stems driven by transpirational pull.

Question #31 Key: (C)BIOLOGY
06. Digestion/Nutrition

The inactive pancreatic proenzyme trypsinogen is converted into active trypsin in the duodenum ...

CORE CONCEPT & DERIVATION

Pancreatic zymogens remain inactive until reaching the intestinal lumen to prevent autodigestion of pancreatic acinar tissue.

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

- Enterokinase (enteropeptidase) is a brush-border enzyme bound to the duodenal epithelial membrane.
- It cleaves a specific hexapeptide from the N-terminus of trypsinogen, unmasking trypsin's active site to trigger subsequent activation of all other pancreatic zymogens.

Why other options are incorrect:

- **Option A:** Hydrochloric acid activates pepsinogen to pepsin in the stomach, not trypsinogen in the duodenum.
- **Option B:** Pepsin acts in the stomach and is inactivated by the neutral-to-alkaline pH of the duodenum.
- **Option D:** Erepsin is an antiquated term for a mixture of mucosal peptidases that complete peptide digestion.

Question #32 Key: (B)BIOLOGY
06. Digestion/Nutrition

The breakdown of large dietary lipid droplets into minute, suspended droplets (emulsification) ...

CORE CONCEPT & DERIVATION

Lipid digestion requires mechanical dispersal into fine emulsion droplets to provide sufficient surface area for water-soluble lipases to function.

Formula / Rule / Reaction:

Large Fat Globules + Bile Salts → Emulsified Droplets (Micelles)

Solution:

- Bile salts are amphipathic molecules containing hydrophobic and hydrophilic faces.
- They adsorb to the surface of large fat globules, reducing interfacial tension and dispersing them into micro-droplets, preventing coalescence.

Why other options are incorrect:

- **Option A:** Pancreatic lipase catalyses chemical ester bond hydrolysis of triglycerides; it cannot emulsify large droplets on its own.
- **Option C:** Trypsin is an endopeptidase that digests proteins.
- **Option D:** Chymotrypsin is a proteolytic enzyme targeting aromatic amino acid residues.

Question #33 Key: (C)BIOLOGY
09. Respiration / Gaseous Exchange

The central anatomical compartment of the thoracic cavity situated between the two pleural sacs...

CORE CONCEPT & DERIVATION

The thoracic cavity is partitioned into lateral pleural cavities containing the lungs and a thick central connective tissue septum.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The mediastinum is the interpleural compartment extending from the sternum anteriorly to the vertebral column posteriorly.
- It encloses the pericardium, heart, great vessels, trachea, oesophagus, and thymus.

Why other options are incorrect:

- **Option A:** The periosteum is the dense fibrous membrane covering bone surfaces.
- **Option B:** An infundibulum is a funnel-shaped stalk or passage (such as the pituitary stalk or fallopian tube segment).
- **Option D:** The pulmonary hilum is the medial depression where bronchi, vessels, and nerves enter each lung.

Question #34 Key: (D)BIOLOGY
07. Circulation / Transport

Oxygenated blood returning to the human heart from the lungs enters the left atrium via:

CORE CONCEPT & DERIVATION

Pulmonary circulation conveys deoxygenated blood to the alveolar capillary beds and returns oxygenated blood to the left systemic chambers.

Formula / Rule / Reaction:

Lungs $\xrightarrow{4 \text{ Pulmonary Veins}}$ Left Atrium $\xrightarrow{\text{Bicuspid Valve}}$ Left Ventricle

Solution:

- Two pulmonary veins emerge from the hilum of each lung, resulting in four pulmonary veins entering the posterior wall of the left atrium.
- They are unique in carrying oxygen-rich blood under relatively low pressure.

Why other options are incorrect:

- **Option A:** The superior vena cava returns deoxygenated systemic blood from the head, neck, and upper extremities to the right atrium.
- **Option B:** The inferior vena cava drains deoxygenated blood from the abdomen and lower limbs into the right atrium.
- **Option C:** The coronary sinus drains deoxygenated blood from the myocardium into the right atrium.

Question #35 Key: (C)BIOLOGY
05. Acellular Life

Because viruses lack autonomous metabolic machinery and cannot reproduce outside a host cell, t...

CORE CONCEPT & DERIVATION

Viruses do not possess independent metabolic machinery, cytoplasm, or ribosome-mediated protein synthesis mechanisms.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Viruses are obligate intracellular parasites that must infect living host cells.
- They hijack the host cell's enzymes, ribosomes, and energy reserves to replicate viral nucleic acids and assemble new virions.

Why other options are incorrect:

- **Option A:** Autotrophs synthesize their own organic molecules from inorganic carbon sources, which acellular viruses cannot do.
- **Option B:** Facultative heterotrophs can switch between parasitic and free-living saprophytic lifestyles; viruses cannot replicate extracellularly.
- **Option D:** Predators are multicellular or cellular organisms that hunt and ingest prey.

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

Which of the following viral pathogens is transmitted parenterally through contaminated blood p...

CORE CONCEPT & DERIVATION

Blood-borne pathogens require direct introduction into the systemic bloodstream via compromised mucosal barriers or percutaneous inoculation.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- HIV is a retrovirus transmitted through contaminated blood transfusions, unsterilized surgical instruments, needle sharing among intravenous drug users, and unprotected sexual intercourse.
- It infects CD4⁺ T helper lymphocytes, ultimately leading to Acquired Immunodeficiency Syndrome (AIDS).

Why other options are incorrect:

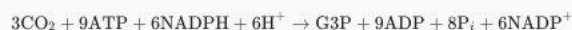
- **Option B:** Influenza virus is an orthomyxovirus transmitted via airborne respiratory aerosols.
- **Option C:** Morbillivirus causes measles and spreads through respiratory droplets.
- **Option D:** *Vibrio cholerae* is a water-borne bacterium transmitted via the fecal-oral route.

Question #37 Key: (A)BIOLOGY
04. Bioenergetics

The light-independent phase (Calvin-Benson cycle) of photosynthesis is directly responsible for...

CORE CONCEPT & DERIVATION

Photosynthesis occurs in two phases: light-dependent reactions generating assimilatory power, and light-independent reactions fixing carbon dioxide into sugars.

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

- The Calvin cycle operates in the stroma using the chemical energy of ATP and NADPH synthesized during the light reactions.
- Carbon dioxide is fixed by RuBisCO to produce glyceraldehyde-3-phosphate (G3P), which is assembled into energy-rich carbohydrates like glucose.

Why other options are incorrect:

- **Option B:** Photolysis of water occurs at Photosystem II in the thylakoid lumen during the light-dependent phase.
- **Option C:** Photophosphorylation producing ATP occurs across the thylakoid membrane during the light reactions.
- **Option D:** Production of NADPH occurs at Photosystem I via ferredoxin-NADP⁺ reductase during light reactions.

Question #38 Key: (C)BIOLOGY
04. Bioenergetics

In the porphyrin head of a chlorophyll molecule, light absorption promotes electrons to higher ...

CORE CONCEPT & DERIVATION

Chlorophyll consists of a flat, light-absorbing porphyrin ring coordinated around a central divalent metallic cation, anchored by a phytol tail.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- A single magnesium ion (Mg^{2+}) occupies the exact center of the porphyrin ring, coordinated to four pyrrole nitrogen atoms.
- The delocalized π -electron system coordinated around magnesium absorbs blue and red wavelengths, raising electrons to an excited state to initiate photochemical charge separation.

Why other options are incorrect:

- **Option A:** Carbon forms the rigid skeleton of the pyrrole rings.
- **Option B:** Hydrogen atoms saturate the peripheral hydrocarbon bonds.
- **Option D:** Nitrogen atoms coordinate with the central magnesium atom, but the central metal atom defining the complex is magnesium.

Question #39 Key: (B)BIOLOGY
02. Biomolecules

Which of the following proteins possesses an insoluble, elongated fibrous structure providing m...

CORE CONCEPT & DERIVATION

Proteins are classified structurally into fibrous proteins (linear, insoluble, structural) and globular proteins (spherical, soluble, functional).

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Collagen consists of a right-handed triple helix of polypeptide chains assembled into high-tensile fibrils.
- It is water-insoluble and provides mechanical strength to tendons, skin, cartilage, and bone matrix.

Why other options are incorrect:

- **Option A:** Pepsin is a soluble globular proteolytic enzyme.
- **Option C:** Haemoglobin is a soluble globular tetrameric transport protein.
- **Option D:** Insulin is a soluble globular peptide hormone.

Question #40 Key: (D)BIOLOGY
02. Biomolecules

Which physiological role is characteristic of lipids (subcutaneous adipose tissue) rather than ...

CORE CONCEPT & DERIVATION

While proteins perform structural, catalytic, and transport functions, biological insulation is primarily mediated by triglycerides in adipose tissue.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Subcutaneous adipose tissue contains stored triglycerides that exhibit low thermal conductivity.
- This fatty layer forms an insulating barrier that reduces conductive heat loss to the external environment.

Why other options are incorrect:

- **Option A:** Cytoskeletal support is mediated by protein polymers (actin microfilaments, tubulin microtubules, intermediate filaments).
- **Option B:** Biological catalysis is executed by protein enzymes.
- **Option C:** Transmembrane solute transport is carried out by integral protein channels and carriers.

Question #41 Key: (C)BIOLOGY
02. Biomolecules

A lipid molecule composed of three fatty acid hydrocarbon chains esterified to a single glycerol...

CORE CONCEPT & DERIVATION

Acylglycerols are formed through the condensation esterification of fatty acids with the hydroxyl groups of glycerol.

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

- Glycerol is a trihydroxy alcohol (propane-1,2,3-triol).
- When all three hydroxyl ($-\text{OH}$) groups undergo ester bond formation with three fatty acids, a neutral triacylglycerol (triglyceride) is formed.

Why other options are incorrect:

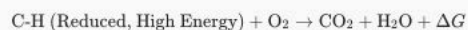
- **Option A:** A monoglyceride contains only one fatty acid chain esterified to glycerol.
- **Option B:** A diglyceride contains two esterified fatty acids.
- **Option D:** A phospholipid contains two fatty acids and a modified phosphate head group attached to glycerol.

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

Which covalent bond present in abundance within carbohydrates and lipids serves as the primary ...

CORE CONCEPT & DERIVATION

The oxidation of organic substrates releases free energy when low-electronegativity carbon-hydrogen bonds are exchanged for high-electronegativity polar bonds.

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

- The carbon-hydrogen (C-H) bond contains shared electrons held at a relatively high potential energy level.
- Enzymatic dehydrogenation cleaves these bonds during glycolysis and the Krebs cycle, yielding reduced coenzymes (NADH and FADH₂) to drive ATP synthesis.

Why other options are incorrect:

- **Option A:** C=O bonds are highly oxidized, low-potential-energy bonds.
- **Option C:** C-N bonds form the structural backbone of peptide chains and are not the primary respiratory energy source.
- **Option D:** O-H bonds are already fully oxidized and stable.

Question #43 Key: (C)BIOLOGY
02. Biomolecules

Water acts as an efficient thermal buffer in biological systems because of which specific physi...

CORE CONCEPT & DERIVATION

Thermal stability in organisms requires an internal medium that can absorb or release large amounts of heat with minimal changes in temperature.

Formula / Rule / Reaction:

$$Q = mc\Delta T \quad (c_{\text{water}} \approx 4.184 \text{ J/g} \cdot ^\circ\text{C})$$

Solution:

- Water has an exceptionally high specific heat capacity due to its extensive intermolecular hydrogen-bonding network.
- A large amount of thermal energy is absorbed to break hydrogen bonds before the kinetic motion of water molecules can increase, stabilizing internal temperature against environmental fluctuations.

Why other options are incorrect:

- **Option A:** High molecular polarity accounts for solvent properties, not directly for thermal buffering.
- **Option B:** Water exhibits polar hydrogen bonding, not non-polar interactions.
- **Option D:** While water has a high boiling point, specific heat capacity is the exact physical parameter governing thermal stabilization.

Question #44 Key: (D)BIOLOGY
01. Cell

Which of the following macromolecular classes does NOT form a structural constituent of the flu...

CORE CONCEPT & DERIVATION

The fluid mosaic model defines biological membranes as phospholipid bilayers interspersed with proteins and carbohydrate conjugates.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Plasma membranes are composed of a phospholipid bilayer, embedded integral and peripheral proteins, cholesterol, and external glycoproteins and glycolipids.
- Nucleoproteins are complexes of nucleic acids and proteins (such as histones and chromatin) found in the nucleus and ribosomes, not within membranes.

Why other options are incorrect:

- **Option A:** Glycoproteins form cell-surface receptors and the glycocalyx.
- **Option B:** Glycolipids are crucial membrane components involved in cell-cell recognition.
- **Option C:** Phospholipids constitute the fundamental structural amphipathic lipid bilayer.

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

Among the major classes of carbohydrates, which group is characteristically the sweetest in tas...

CORE CONCEPT & DERIVATION

Carbohydrates are classified based on polymerization into monosaccharides, oligosaccharides, and polysaccharides, showing distinct sweetness and solubility trends.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Monosaccharides are simple single-unit sugars with low molecular weight and high water solubility.
- They bind readily to human taste receptors on the tongue; fructose (a ketohexose monosaccharide) is the sweetest of all naturally occurring dietary sugars.

Why other options are incorrect:

- **Option B:** Disaccharides (like sucrose and maltose) are sweet, but as a class, monosaccharides (specifically fructose) have the highest relative sweetness index.
- **Option C:** Oligosaccharides possess low solubility and minimal sweetness.
- **Option D:** Polysaccharides (like starch and cellulose) are insoluble, tasteless polymers.

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

Which organelle is referred to as the 'suicidal bag' of the animal cell due to its high concent...

CORE CONCEPT & DERIVATION

Certain organelles house broad-spectrum hydrolytic enzymes isolated behind a single lipid membrane to prevent accidental destruction of the host cell.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Lysosomes contain over 40 distinct hydrolytic enzymes (proteases, lipases, nucleases).
- Under conditions of severe cellular damage or programmed cell death (autolysis), lysosomal membranes rupture, releasing enzymes into the cytoplasm that digest the cell from within.

Why other options are incorrect:

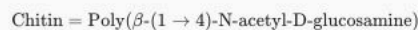
- **Option A:** Peroxisomes contain catalase and oxidases involved in hydrogen peroxide detoxification, not autolytic suicide.
- **Option C:** Glyoxysomes are specialized plant microbodies involved in the glyoxylate cycle.
- **Option D:** A phagosome is a temporary endocytic vacuole formed during engulfment of particles.

Question #47 Key: (C)BIOLOGY
01. Cell

The rigid structural cell wall of fungi is chemically composed of:

CORE CONCEPT & DERIVATION

Fungi possess a unique cell wall chemistry that distinguishes them phylogenetically from plants, bacteria, and animals.

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

- The fungal cell wall consists predominantly of chitin, a tough, nitrogen-containing polysaccharide.
- It provides structural rigidity, osmotic resistance, and protection against mechanical damage.

Why other options are incorrect:

- **Option A:** Cellulose forms the structural framework of plant and algal cell walls.
- **Option B:** Lignin is a complex aromatic polymer that reinforces secondary cell walls in vascular plants.
- **Option D:** Peptidoglycan (murein) forms the structural cell wall of eubacteria.

Question #48 Key: (C)BIOLOGY
01. Cell

Which organelle in neurons is responsible for sorting, modifying, and packaging neurosecretory ...

CORE CONCEPT & DERIVATION

Neurotransmitters and neuromodulators must be post-translationally modified, sorted, and packed into membrane-bound vesicles prior to axonal transport.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The Golgi apparatus in the neuronal soma receives synthesized peptide precursors from the rough endoplasmic reticulum.
- It cleaves, glycosylates, and packages these substances into synaptic vesicles that are transported via anterograde axoplasmic flow to the axon terminal.

Why other options are incorrect:

- **Option A:** Glyoxysomes are plant organelles that convert fats to carbohydrates in germinating seeds.
- **Option B:** Peroxisomes metabolize long-chain fatty acids and detoxify hydrogen peroxide.
- **Option D:** The rough endoplasmic reticulum synthesizes raw polypeptides but does not package final synaptic vesicles.

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

The inner membrane of a mitochondrion projects into the internal matrix cavity via deep, shelf-...

CORE CONCEPT & DERIVATION

Mitochondria have a double-membrane envelope where the inner membrane is folded to maximize the surface area for oxidative phosphorylation.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The inner mitochondrial membrane forms deep, invaginated folds known as cristae.
- Cristae house respiratory chain complexes I through IV, ubiquinone, cytochrome c, and ATP synthase complexes.

Why other options are incorrect:

- **Option A:** Cisternae are the flattened flattened stacks characteristic of the endoplasmic reticulum and Golgi apparatus.
- **Option C:** Chromatin is the complex of genomic DNA and histone proteins inside the nucleus.
- **Option D:** Grana are stacks of thylakoid discs inside chloroplasts.

Question #50 Key: (C)BIOLOGY
01. Cell

In cellular signal transduction pathways, the membrane-associated protein adenylyl cyclase func...

CORE CONCEPT & DERIVATION

Adenylyl cyclase (adenylate cyclase) is an integral transmembrane effector protein activated by heterotrimeric G-protein α -subunits.

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

- Adenylyl cyclase operates as an enzyme that converts ATP into cyclic adenosine monophosphate (cAMP) and inorganic pyrophosphate.
- cAMP then acts as a second messenger, activating protein kinase A (PKA) to elicit intracellular metabolic responses.

Why other options are incorrect:

- **Option A:** Ligand-gated channels facilitate passive ion transport across the membrane upon ligand binding; they lack catalytic activity.
- **Option B:** Carrier proteins bind solutes to undergo conformational shifts for transmembrane transport.
- **Option D:** cAMP is the secondary messenger, whereas adenylyl cyclase is the catalytic enzyme that synthesizes it.

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

Glycogen granules and lipid droplets stored within the cytoplasm are classified as:

CORE CONCEPT & DERIVATION

Cytoplasmic constituents are categorized into active metabolic living organelles and passive non-living storage deposits known as inclusions.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Cell inclusions are non-living, non-metabolizing metabolic byproducts or nutrient reserves stored within the cytosol.
- Classic examples in animal cells include stored glycogen rosettes in hepatocytes and lipid droplets in adipocytes.

Why other options are incorrect:

- **Option A:** Cell organelles are active, organized metabolic subunits (such as mitochondria or lysosomes).
- **Option C:** The cytoplasmic matrix (cytosol) is the semi-fluid ground substance in which inclusions and organelles are suspended.
- **Option D:** Non-membranous organelles are complex macromolecular machines like ribosomes and centrioles, not passive nutrient aggregates.

Question #52 Key: (C)BIOLOGY
08. Immunity

Acquired immunity developed through administration of a vaccine containing attenuated or inacti...

CORE CONCEPT & DERIVATION

Immunity is active when host B and T lymphocytes generate an endogenous response, and artificial when induced through clinical intervention.

Formula / Rule / Reaction:

Vaccine (Antigenic Inoculation) → Host Clonal Selection → Antibodies + Memory Cells

Solution:

- Vaccination introduces harmless antigenic fragments artificially.
- Because the recipient's immune cells actively produce antibodies and long-lived memory B and T cells, it represents artificial active immunity.

Why other options are incorrect:

- **Option A:** Natural passive immunity occurs via transplacental transfer of maternal IgG or colostral IgA.
- **Option B:** Natural active immunity results from recovering from an actual clinical infection.
- **Option D:** Artificial passive immunity involves injecting pre-formed exogenous antibodies (such as antivenom or rabies immunoglobulin).

Question #53 Key: (D)BIOLOGY
07. Circulation / Transport

The human lymphatic system comprises all of the following structures EXCEPT:

CORE CONCEPT & DERIVATION

The lymphatic system consists of fluid lymph, conducting lymphatic vessels, and specialized lymphoid tissues that filter interstitial fluid and mount immune responses.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Lymphoid organs include primary organs (bone marrow, thymus) and secondary organs (spleen, lymph nodes, tonsils, Peyer's patches).
- The lungs are primary organs of the respiratory system; although they contain mucosal lymphoid tissue (BALT), they are not lymphoid organs.

Why other options are incorrect:

- **Option A:** Lymphoid masses (such as tonsils and lymph nodes) are integral functional components of the lymphatic system.
- **Option B:** Lymphatic vessels form the essential network collecting and returning interstitial lymph to the bloodstream.
- **Option C:** The spleen is the largest secondary lymphoid organ in the body.

Question #54 Key: (C)BIOLOGY
02. Biomolecules

The unique structural macromolecular polymer forming the rigid framework of eubacterial cell wa...

CORE CONCEPT & DERIVATION

Bacterial cell walls rely on a rigid covalent mesh to prevent osmotic lysis under hypotonic turgor pressure.

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

- Peptidoglycan (also known as murein) is a heteropolymer composed of alternating N-acetylglucosamine (NAG) and N-acetylmuramic acid (NAM) residues.
- These glycan strands are covalently linked by short cross-linking peptide chains, forming a rigid sacculus unique to eubacteria.

Why other options are incorrect:

- **Option A:** Simple polysaccharides lack the peptide cross-bridges that define bacterial murein.
- **Option B:** Globular proteins perform dynamic enzymatic or transport functions rather than forming bacterial cell wall sacculi.
- **Option D:** Cholesterol is a sterol found in eukaryotic membranes; it is absent in bacterial cell walls and membranes (except in *Mycoplasma*).

Question #55 Key: (C)BIOLOGY
17. Biotechnology

The horizontal transfer of genetic material from one bacterium to another mediated by a bacteriophage...

CORE CONCEPT & DERIVATION

Genetic recombination in bacteria occurs horizontally via three primary mechanisms: conjugation, transformation, and virus-mediated transduction.

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

- Transduction is the process whereby a bacteriophage accidentally packages donor bacterial DNA fragments during viral assembly.
- Upon subsequent infection of a new bacterial host, this genetic material is injected and incorporated into the recipient genome.

Why other options are incorrect:

- **Option A:** Conjugation requires direct cell-to-cell contact and transfer across a conjugative sex pilus.
- **Option B:** Transformation is the direct uptake of naked extracellular DNA fragments from the surrounding medium.
- **Option D:** Transposition is the autonomous intracellular movement of transposons within a DNA molecule.

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

All of the following are physical methods used to control and destroy bacterial populations EXC...

CORE CONCEPT & DERIVATION

Microbial control modalities are categorized strictly into physical agents (heat, radiation, filtration) and chemical agents (antiseptics, disinfectants, sterilants).

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Autoclaving (moist heat under pressure), boiling, and ionizing gamma radiation are physical interventions that denature macromolecules.
- Antiseptics are antimicrobial chemical formulations (such as chlorhexidine or iodine) applied topically to living tissue.

Why other options are incorrect:

- Option A:** Steam sterilization under pressure is a physical thermal method.
- Option B:** Boiling water utilizes thermal energy, which is a physical method.
- Option C:** Gamma irradiation and ultraviolet light are physical electromagnetic methods.

Question #57 Key: (C)BIOLOGY
08. Immunity

Which of the following interventions stimulates the human immune system to develop specific, lo...

CORE CONCEPT & DERIVATION

Immunological protection against pathogenic microbes requires presentation of antigens to prime adaptive memory B cells.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Vaccination introduces harmless, specific antigenic epitopes into the host.
- This stimulates follicular B cells to differentiate into plasma cells that secrete specific antibodies and generate long-lived memory B cells.

Why other options are incorrect:

- Option A:** Radiotherapy utilizes ionizing radiation to destroy malignant cells; it causes immunosuppression.
- Option B:** Chemotherapy uses cytotoxic drugs to kill rapidly dividing cancer cells, depleting leukocytes.
- Option D:** Antibiotics are exogenous chemical agents that kill bacteria directly without generating host immune memory.

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

Following fertilization in the ampulla of the fallopian tube, the developing blastocyst takes a...

CORE CONCEPT & DERIVATION

After fertilization, the zygote undergoes cleavage into a morula and blastocyst while propelled through the oviduct by ciliary action and tubal peristalsis.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- According to the Federal Board biology curriculum, the tubal transit time for the dividing zygote to reach the uterine lumen is approximately 3 to 6 days.
- The blastocyst enters the uterine cavity around day 4 to 5, floats freely for 1 to 2 days, and begins implantation on day 6 to 7.

Why other options are incorrect:

- Option A:** 10 to 12 days is far past the window of implantation, which is fully completed by day 9 to 10.
- Option C:** 12 to 15 days represents the onset of the next menstrual period if fertilization does not occur.
- Option D:** 18 to 21 days is biologically inaccurate for tubal transit.

Question #59 Key: (D)BIOLOGY
14. Reproduction

Optimal human spermatogenesis within the seminiferous tubules occurs at a scrotal temperature o...

CORE CONCEPT & DERIVATION

Meiotic progression and differentiation of spermatogonia require a temperature slightly lower than the core body temperature.

Formula / Rule / Reaction:

$$T_{\text{scrotal}} = T_{\text{core}} - (2 \times 10^{-3})^{\circ}\text{C} = 37^{\circ}\text{C} - 2^{\circ}\text{C} \approx 35^{\circ}\text{C}$$

Solution:

- The human testes are suspended outside the abdominopelvic cavity within the scrotum to maintain a cooler microenvironment.
- Spermatogenic enzymes are thermosensitive; optimal production of functional spermatozoa occurs at approximately 34 °C to 35 °C.

Why other options are incorrect:

- Option A:** 37 °C is normal internal abdominal core temperature, which causes degeneration of spermatogenic epithelium and infertility (as seen in cryptorchidism).
- Option B:** 30 °C is excessively subnormal and impairs testicular metabolic rate.
- Option C:** 32 °C is below the physiological operating temperature of human testicular tissue.

Question #60 Key: (A)BIOLOGY
14. Reproduction

In human females, follicle-stimulating hormone (FSH) secreted by the anterior pituitary directl...

CORE CONCEPT & DERIVATION

Pituitary gonadotropins control the female ovarian cycle by regulating follicular development and steroidogenesis.

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

- Follicle-stimulating hormone binds to G-protein-coupled receptors on ovarian granulosa cells.
- This promotes the proliferation of granulosa layers, growth of primary and secondary follicles, and secretion of 17-β-estradiol.

Why other options are incorrect:

- Option B:** Ovulation is triggered by a massive mid-cycle surge of luteinizing hormone (LH), not FSH.
- Option C:** Implantation is facilitated by progesterone secreted by the corpus luteum, which prepares the endometrium.
- Option D:** Menstruation is initiated by the sudden withdrawal of progesterone and estrogen following corpus luteum regression.

Question #61 Key: (A)BIOLOGY
14. Reproduction

Interstitial cells of Leydig situated between the seminiferous tubules of the testes are respon...

CORE CONCEPT & DERIVATION

The endocrine function of the mammalian testis resides in interstitial stromal cells responding to pituitary luteinizing hormone (LH).

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

- Leydig cells are located in the interstitial connective tissue vascular spaces surrounding seminiferous tubules.
- In response to LH stimulation, they convert cholesterol into androgens, predominantly testosterone.

Why other options are incorrect:

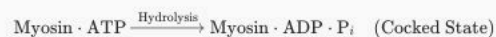
- **Option B:** Follicle-stimulating hormone is synthesized and released by gonadotroph cells of the anterior pituitary gland.
- **Option C:** Spermatozoa are produced by the germinal epithelium of seminiferous tubules supported by Sertoli cells.
- **Option D:** Inhibin is synthesized and secreted by Sertoli cells to provide negative feedback on pituitary FSH release.

Question #62 Key: (C)BIOLOGY
11. Support & Movement

During skeletal muscle contraction, the resetting and detachment of actin-myosin cross-bridges ...

CORE CONCEPT & DERIVATION

The cross-bridge cycle of the sliding filament mechanism is regulated by nucleotide binding and hydrolysis on the myosin globular head.

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

- Binding of a new ATP molecule causes detachment of the myosin head from the actin active site.
- Myosin ATPase then hydrolyzes ATP into ADP and inorganic phosphate (P_i), releasing energy to cock the myosin head into its high-energy conformation.

Why other options are incorrect:

- **Option A:** ATP is not consumed via redox oxidation during cross-bridge cycling.
- **Option B:** ATP does not undergo chemical reduction during muscle contraction.
- **Option D:** ATP synthesis occurs via mitochondrial oxidative phosphorylation and creatine kinase, not during cross-bridge mechanical work.

Question #63 Key: (A)BIOLOGY
11. Support & Movement

The clinical condition characterized by chronic inflammation and degenerative breakdown of articular cartilage is...

CORE CONCEPT & DERIVATION

Joint disorders involving degradation of the articular cartilage surface accompanied by inflammation of the capsule and synovium are termed arthritis.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Osteoarthritis is a degenerative joint disease where mechanical stress and enzymatic activity break down hyaline articular cartilage.
- This results in reduced joint space, bone friction, formation of marginal osteophytes, and joint pain.

Why other options are incorrect:

- **Option B:** Osteoporosis is a systemic skeletal condition characterized by reduced bone mineral density and increased fracture susceptibility.
- **Option C:** Arteriosclerosis is the thickening, hardening, and loss of elasticity of arterial blood vessel walls.
- **Option D:** Osteosclerosis is an abnormal increase in bone density or calcification.

Question #64 Key: (A)BIOLOGY
12. Nervous Coordination

Tetany, characterized by involuntary spastic muscle contractions, is precipitated by which electrolyte imbalance?

CORE CONCEPT & DERIVATION

Extracellular calcium ions stabilize neuronal membrane excitability by gating voltage-dependent sodium channels.

Formula / Rule / Reaction:

$\downarrow [Ca^{2+}]_{\text{plasma}} \rightarrow \text{Decreased Threshold Potential} \rightarrow \text{Spontaneous Depolarization}$

Solution:

- Hypocalcaemia lowers the threshold required to open voltage-gated sodium channels in peripheral motor nerve axons.
- This produces axonal hyperexcitability, leading to rapid, repetitive trains of action potentials and sustained muscle spasms (tetany).

Why other options are incorrect:

- **Option B:** Hypercalcaemia increases the threshold for excitation, causing muscle weakness, lethargy, and depressed reflexes.
- **Option C:** Hypomagnesaemia can indirectly lower calcium, but hypocalcaemia is the direct classical clinical trigger of tetanic spasms.
- **Option D:** Hypermagnesaemia acts as a CNS depressant and blocks neuromuscular transmission, resulting in flaccid paralysis.

Question #65 Key: (A)BIOLOGY
09. Respiration / Gaseous Exchange

What is the primary physiological function of myoglobin in skeletal and cardiac muscle fibers?

CORE CONCEPT & DERIVATION

Myoglobin is a monomeric hemeprotein that exhibits a hyperbolic oxygen dissociation curve with a much higher oxygen affinity than hemoglobin.

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

- Due to its high oxygen affinity, myoglobin remains saturated at normal resting tissue oxygen tensions.
- During strenuous exercise, when capillary oxygen supply drops below critical levels, myoglobin releases its stored oxygen to keep mitochondrial respiration going.

Why other options are incorrect:

- **Option B:** Myoglobin does not bind or store carbon dioxide.
- **Option C:** Systemic oxygen transport in the circulatory system is carried out by tetrameric hemoglobin inside erythrocytes.
- **Option D:** Carbon dioxide is transported in blood primarily as bicarbonate ions, carbaminohemoglobin, and dissolved gas, not by myoglobin.

Question #66 Key: (B)BIOLOGY
11. Support & Movement

A freely movable joint where articulating bone ends are capped with hyaline articular cartilage...

CORE CONCEPT & DERIVATION

Joints are classified structurally according to the presence of a fluid-filled cavity and the intervening connecting tissue.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- A synovial joint (diarthrosis) is defined by an articular capsule composed of an outer fibrous layer and an inner synovial membrane.
- The membrane secretes synovial fluid into the joint cavity to lubricate the smooth hyaline cartilage ends, enabling frictionless movement.

Why other options are incorrect:

- **Option A:** Cartilaginous joints (amphiarthroses, such as pubic symphysis) unite bones via fibrocartilage or hyaline cartilage without a synovial cavity.
- **Option C:** Fibrous joints (such as cranial sutures) join bones tightly with dense fibrous connective tissue and allow no movement.
- **Option D:** Synarthrodial is a functional term for completely immovable joints.

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

Genes located close to each other on the same chromosome that tend to be co-inherited into gametes...

CORE CONCEPT & DERIVATION

Mendel's second law applies only to genes residing on non-homologous chromosomes; genes residing on the same chromosome physical syntenic exhibit genetic linkage.

Formula / Rule / Reaction:

$$\text{Recombination Frequency} < 50\% \implies \text{Genetic Linkage}$$

Solution:

- Linked genes are positioned on the same linear DNA molecule of a chromosome.
- Unless separated by crossing-over during prophase I of meiosis, they segregate together into the same gamete, yielding non-Mendelian parental phenotypic ratios.

Why other options are incorrect:

- **Option B:** Dependent genes is an informal term with no defined genetic status.
- **Option C:** Recombinant genes are those that have undergone crossing-over to produce non-parental allele combinations.
- **Option D:** Independent genes reside on distinct chromosomes and assort independently according to Mendelian ratios (9:3:3:1).

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

Classical Mendelian monohybrid inheritance in garden peas is governed by which dominance relationship...

CORE CONCEPT & DERIVATION

Gregor Mendel's original law of dominance establishes that in a heterozygote, one allele completely masks the phenotypic expression of the alternative allele.

Formula / Rule / Reaction:

$$\text{Genotype: } Tt \implies \text{Phenotype: Tall (Identical to } TT)$$

Solution:

- In pea plants (*Pisum sativum*), all seven traits studied by Mendel exhibited complete dominance.
- Heterozygous individuals displayed the exact phenotype of the homozygous dominant parent, yielding a classic 3:1 phenotypic ratio in the F₂ generation.

Why other options are incorrect:

- **Option B:** Incomplete dominance yields an intermediate blending phenotype in heterozygotes (as in *Antirrhinum majus* flower color).
- **Option C:** Co-dominance results in the simultaneous, distinct expression of both alleles (as in the AB blood group).
- **Option D:** Multiple allelism describes the existence of three or more alleles within a population (such as the ABO system).

Question #69 Key: (A)CHEMISTRY
06. Solids

Solid crystalline iodine ([Formula]) forms which structural class of crystal lattice?

CORE CONCEPT & DERIVATION

Crystalline solids are classified according to the nature of the constituent particles and the intermolecular forces holding them in lattice sites.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- In crystalline iodine, the lattice positions are occupied by discrete non-polar diatomic I_2 molecules.
- These molecules are held together by relatively weak London dispersion forces, which gives iodine a low melting point and allows it to sublime easily.

Why other options are incorrect:

- **Option B:** Ionic crystals (such as NaCl) are composed of alternating cations and anions held by strong electrostatic attractions.
- **Option C:** Covalent network crystals (such as diamond and quartz) consist of continuous covalent networks.
- **Option D:** Metallic crystals (such as copper and iron) consist of positive metal ions embedded in a delocalized sea of electrons.

Question #70 Key: (D)CHEMISTRY
05. Liquids

When two ice cubes are firmly pressed together, they fuse into a single ice cube primarily due ...

CORE CONCEPT & DERIVATION

Under the phenomenon of regelation, application of external pressure lowers the melting point of ice, causing superficial melting followed by refreezing upon release of pressure.

Formula / Rule / Reaction:

Pressure Applied $\rightarrow$ Melting $\xrightarrow{\text{Pressure Released}}$ Re-formation of H-Bonds

Solution:

- Increasing pressure at the contact interface lowers the melting point below 0°C , producing a thin liquid film of water.
- When the pressure is released, the melting point returns to 0°C ; the liquid water refreezes as intermolecular hydrogen bonds reform across the interface.

Why other options are incorrect:

- **Option A:** Pure dipole-dipole forces are much weaker than directional hydrogen bonds and do not drive regelation fusion.
- **Option B:** No intramolecular covalent O-H bonds are broken or created between water molecules.
- **Option C:** London dispersion forces are weak non-specific interactions that play a secondary role in water's lattice cohesion.

Question #71 Key: (D)CHEMISTRY
07. Equilibrium

For the Haber synthesis reaction [Formula], which procedure continuously maximizes the yield o...

CORE CONCEPT & DERIVATION

Le Chatelier's principle dictates that removing a product from an equilibrium mixture shifts the equilibrium forward to replace it.

Formula / Rule / Reaction:

$$Q_c = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3} < K_c \implies \text{Forward Shift}$$

Solution:

- Condensing and continuously withdrawing liquid NH_3 lowers product concentration in the gas phase.
- To restore equilibrium, the forward synthesis reaction proceeds continuously, maximizing the net yield of ammonia.

Why other options are incorrect:

- **Option A:** The forward reaction is exothermic ($\Delta H < 0$); increasing temperature shifts equilibrium to the left, decreasing yield.
- **Option B:** Decreasing pressure favors the side with more moles of gas (reactants: 4 moles), decreasing ammonia yield.
- **Option C:** Increasing vessel volume decreases system pressure, shifting equilibrium to the left.

Question #72 Key: (A)CHEMISTRY
07. Equilibrium

A high operating pressure of approximately 200 atm is employed in the industrial Haber process ...

CORE CONCEPT & DERIVATION

According to Le Chatelier's principle, an increase in external pressure favors the side of a gaseous equilibrium system with fewer moles.

Formula / Rule / Reaction:



Solution:

- The forward reaction results in a volume contraction (from 4 moles of gaseous reactants to 2 moles of gaseous product).
- Applying a high pressure of 200 atm drives the position of equilibrium to the right, significantly boosting the percentage yield of ammonia.

Why other options are incorrect:

- **Option B:** High pressure increases, rather than decreases, the yield of ammonia.
- **Option C:** High pressure increases collision frequency, which accelerates the rate of reaction.
- **Option D:** Generating and containing 200 atm requires thick-walled steel reactors, which increases rather than decreases capital and maintenance costs.

Question #73 Key: (D)CHEMISTRY
07. Equilibrium

By which of the following operational factors is the chemical equilibrium state attained in the...

CORE CONCEPT & DERIVATION

A catalyst speeds up both the forward and reverse reaction rates equally by providing an alternate reaction pathway with a lower activation energy.

Formula / Rule / Reaction:

$$\text{Rate}_f = k_f[A][B], \quad \text{Rate}_r = k_r[C][D] \quad (k_f \text{ and } k_r \text{ increase by the same factor})$$

Solution:

- A catalyst does not alter the equilibrium constant (K_c) or change the final equilibrium composition.
- Because it lowers the activation energy barrier symmetrically, equilibrium is established much earlier.

Why other options are incorrect:

- **Option A:** Changing temperature alters the value of K_c and shifts the final equilibrium position.
- **Option B:** Pressure changes alter the equilibrium position for reactions where the number of moles of gas changes.
- **Option C:** Increasing reactant concentration changes the equilibrium position without lowering the activation energy.

Question #74 Key: (D)CHEMISTRY
07. Equilibrium

Which of the following is NOT a recognized laboratory or physiological application of a buffer...

CORE CONCEPT & DERIVATION

Buffer solutions resist changes in hydronium ion concentration upon the addition of small amounts of strong acid or base.

Formula / Rule / Reaction:

$$\text{pH} = \text{p}K_a + \log \left(\frac{[\text{Conjugate Base}]}{[\text{Acid}]} \right)$$

Solution:

- Buffers maintain a constant pH for pH meter calibration, tissue preservation, and physiological homeostasis (like the carbonic acid-bicarbonate buffer in blood).
- A buffer cannot determine or predict the unknown concentration of an analyte solute; that requires quantitative analytical methods such as titration or spectrophotometry.

Why other options are incorrect:

- **Option A:** Standard commercial buffers of pH 4.01, 7.00, and 10.01 are used worldwide to calibrate glass electrode pH meters.
- **Option B:** Histological fixatives require buffered solutions to preserve cell morphology and prevent autolysis.
- **Option C:** Blood bicarbonate buffer maintains arterial pH within the narrow window of 7.35 to 7.45.

Question #75 Key: (B)

CHEMISTRY
08. Reaction Kinetics

Which of the following statements regarding the activated complex (transition state) is INCORRE...

CORE CONCEPT & DERIVATION

The activated complex is a temporary, unstable molecular assembly formed during an effective collision, characterized by partially formed and partially broken bonds.

Formula / Rule / Reaction:



Solution:

- The activated complex occupies the maximum potential energy point along the reaction coordinate.
- It has a lifetime on the order of femtoseconds (10^{-15} s) and cannot be isolated as a stable chemical species.

Why other options are incorrect:

- **Option A:** It is a high-energy species relative to both reactants and products.
- **Option C:** It is highly unstable and rapidly decomposes into either products or reactants.
- **Option D:** Potential energy is at its absolute peak at the apex of the reaction barrier.

Question #76 Key: (B)

CHEMISTRY
08. Reaction Kinetics

The unit of the rate constant ([Formula]) is identical to the unit of the rate of reaction fo...

CORE CONCEPT & DERIVATION

The general unit for a chemical rate constant depends directly on the overall reaction order n .

Formula / Rule / Reaction:

$$\text{Unit of } k = (\text{mol} \cdot \text{dm}^{-3})^{1-n} \cdot \text{s}^{-1}$$

Solution:

- For a zero-order reaction, $n = 0$:
- $$\text{Unit of } k = (\text{mol} \cdot \text{dm}^{-3})^{1-0} \cdot \text{s}^{-1} = \text{mol} \cdot \text{dm}^{-3} \cdot \text{s}^{-1}$$
- This matches the unit of reaction rate ($\text{Rate} = -\frac{d[A]}{dt} = \text{mol} \cdot \text{dm}^{-3} \cdot \text{s}^{-1}$).

Why other options are incorrect:

- **Option A:** For a first-order reaction ($n = 1$), the unit of k is s^{-1} .
- **Option C:** For a second-order reaction ($n = 2$), the unit is $\text{dm}^3 \cdot \text{mol}^{-1} \cdot \text{s}^{-1}$.
- **Option D:** For a third-order reaction ($n = 3$), the unit is $\text{dm}^6 \cdot \text{mol}^{-2} \cdot \text{s}^{-1}$.

Question #77 Key: (A)CHEMISTRY
08. Reaction Kinetics

If a reaction is first-order with respect to a reactant, the rate of reaction will change by wh...

CORE CONCEPT & DERIVATION

In first-order kinetics, the instantaneous rate of reaction is directly proportional to the first power of reactant concentration.

Formula / Rule / Reaction:

$$\text{Rate}_1 = k[A]^1, \quad \text{Rate}_2 = k[2A]^1 = 2k[A]^1 = 2(\text{Rate}_1)$$

Solution:

- Because the exponent of the concentration term is 1, any change in reactant concentration produces an identical change in reaction rate.
- Doubling the concentration doubles the rate.

Why other options are incorrect:

- Option B:** The rate would be halved only if the reactant concentration were cut in half.
- Option C:** Reducing to one-fourth would correspond to an inverse-order relationship.
- Option D:** The rate would quadruple only if the reaction were second-order ($[2A]^2 = 4[A]^2$).

Question #78 Key: (A)CHEMISTRY
09. Thermochemistry

The mathematical formulation representing the First Law of Thermodynamics is:

CORE CONCEPT & DERIVATION

The First Law of Thermodynamics states that energy cannot be created or destroyed; the net change in internal energy of a closed system equals the heat transferred plus work performed.

Formula / Rule / Reaction:

$$\Delta E = q + w$$

Solution:

- Under standard IUPAC conventions, heat absorbed by the system ($q > 0$) and work done on the system ($w > 0$) increase its internal energy.
- Thus, $\Delta E = q + w$ represents the fundamental conservation of energy equation.

Why other options are incorrect:

- Option B:** $\Delta E = w - q$ incorrectly subtracts heat added to the system.
- Option C:** $\Delta E = q - w$ is the older engineering convention where work done by the system is defined as positive.
- Option D:** Pressure-volume work is given by $w = -P\Delta V$, not $+P\Delta V$.

Question #79 Key: (B)CHEMISTRY
09. Thermochemistry

One thermochemical calorie (cal) is defined as being equivalent to exactly:

CORE CONCEPT & DERIVATION

The calorie is a non-SI unit of thermal energy, defined as the amount of heat required to raise the temperature of one gram of pure water by 1°C.

Formula / Rule / Reaction:

$$1 \text{ cal} = 4.184 \text{ J}$$

Solution:

- By international standard definition, 1 thermochemical calorie is equal to 4.184 joules.
- Therefore, 1 calorie is 4.184 J (or approximately 4.18 J).

Why other options are incorrect:

- Option A:** 4.184 kJ equals 1,000 calories (1 kcal or dietary Calorie), not 1 calorie.
- Option C:** 0.4184 kJ/mol represents an intensive molar energy unit, not absolute energy.
- Option D:** 0.4184 kJ is equal to 100 calories.

Question #80 Key: (A)CHEMISTRY
09. Thermochemistry

The total thermal energy or heat content of a thermodynamic system measured at constant pressure...

CORE CONCEPT & DERIVATION

Enthalpy (H) is defined as the sum of internal energy and the pressure-volume product of a system.

Formula / Rule / Reaction:

$$H = E + PV \Rightarrow q_p = \Delta H$$

Solution:

- At constant pressure ($\Delta P = 0$), the heat absorbed or evolved by a system equals the change in enthalpy:
- $$\Delta H = \Delta E + P\Delta V = (q_p - P\Delta V) + P\Delta V = q_p$$
- Thus, enthalpy represents the thermal energy content of a system at constant pressure.

Why other options are incorrect:

- Option B:** Internal energy (E) represents the total kinetic and potential energy of all particles, measured as heat transferred at constant volume ($q_v = \Delta E$).
- Option C:** Heat capacity is the amount of heat required to raise the temperature of a given mass by 1 K.
- Option D:** Work done is energy transferred through mechanical force over a distance, not heat content.

Question #81 Key: (B)CHEMISTRY
10. Electrochemistry

Which statement correctly defines the standard electrode potential ([Formula]) of an element?

CORE CONCEPT & DERIVATION

Standard reduction potentials are measured relative to the Standard Hydrogen Electrode (SHE), which is assigned a potential of 0.00 V.

Formula / Rule / Reaction:

$$E_{\text{cell}}^{\circ} = E_{\text{cathode}}^{\circ} - E_{\text{anode}}^{\circ} \quad (T = 298 \text{ K}, P = 1 \text{ atm}, [\text{ion}] = 1.0 \text{ M})$$

Solution:

- Standard conditions require a temperature of 298 K (25 °C), a solute concentration of 1.0 M, and a gas pressure of 1 atm (101.3 kPa).
- The standard electrode potential is measured by connecting the half-cell to a Standard Hydrogen Electrode reference.

Why other options are incorrect:

- Option A:** Omits the 1 M concentration requirement and the reference electrode definition.
- Option C:** An element immersed in pure water does not constitute a standard half-cell with 1 M ion activity.
- Option D:** The potential difference between two arbitrary cells is simply the cell EMF, not the standard potential of a single half-cell.

Question #82 Key: (C)CHEMISTRY
10. Electrochemistry

The oxidation number assigned to any chemical element in its free, uncombined elemental state is...

CORE CONCEPT & DERIVATION

Oxidation state reflects the hypothetical electrical charge on an atom if all bonds to surrounding atoms were completely ionic.

Formula / Rule / Reaction:

$$\text{Oxidation Number of O}_2, \text{N}_2, \text{Cl}_2, \text{P}_4, \text{S}_8, \text{Na}, \text{Fe} = 0$$

Solution:

- In a free element, bonding occurs either between identical atoms with equal electronegativities or as a neutral metallic lattice.
- Because there is no net transfer or shift of electron density, the formal oxidation state is zero.

Why other options are incorrect:

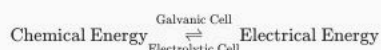
- Option A:** Negative oxidation numbers arise when an atom forms bonds with less electronegative elements.
- Option B:** Positive oxidation states occur when an atom loses electron density to more electronegative atoms.
- Option D:** Non-zero states like ± 1 describe ions (such as Na^+ or Cl^-), not neutral free elements.

Question #83 Key: (A)CHEMISTRY
10. Electrochemistry

The branch of physical chemistry that investigates the interconversion of electrical energy and...

CORE CONCEPT & DERIVATION

Oxidation-reduction reactions involve the transfer of electrons, which can generate an electric current or be driven by an external electrical potential.

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

- Electrochemistry studies both spontaneous redox processes (galvanic/voltaic cells) and non-spontaneous reactions driven by electrical currents (electrolytic cells).

Why other options are incorrect:

- Option B:** Thermochemistry studies heat changes associated with chemical reactions.
- Option C:** Stereochemistry examines the three-dimensional spatial arrangement of atoms within molecules.
- Option D:** Biochemistry focuses on chemical substances and vital processes occurring within living organisms.

Question #84 Key: (A)CHEMISTRY
03. Chemical Bonding

Which of the following hydrogen halide molecules exhibits the greatest difference in electronegativity...

CORE CONCEPT & DERIVATION

Bond polarity is directly proportional to the difference in Pauling electronegativity values (ΔEN) between the bonded atoms.

Formula / Rule / Reaction:

$$\Delta\text{EN}(\text{H-F}) = 4.0 - 2.1 = 1.9$$

Solution:

- Fluorine is the most electronegative element in the periodic table (4.0).
- The electronegativity difference in H-F is 1.9, compared to HCl (0.9), HBr (0.7), and HI (0.4).
- Thus, HF has the largest electronegativity difference and the most polar bond.

Why other options are incorrect:

- Option B:** HCl has $\Delta\text{EN} = 3.0 - 2.1 = 0.9$, significantly lower than HF.
- Option C:** HBr has $\Delta\text{EN} = 2.8 - 2.1 = 0.7$.
- Option D:** HI has $\Delta\text{EN} = 2.5 - 2.1 = 0.4$, which is the least polar among the group.

Question #85 Key: (D)CHEMISTRY
11. S & P Block Elements*First ionization energy decreases progressively down Group IIA because:***CORE CONCEPT & DERIVATION**

Ionization energy depends on the electrostatic attraction between the positive nucleus and the outermost valence electron.

Formula / Rule / Reaction:

$$\text{Force of Attraction} \propto \frac{Z_{\text{eff}}}{r^2}$$

Solution:

- Moving down Group IIA, additional electron shells increase both the atomic radius and the shielding effect.
- This reduces the effective nuclear pull on the valence s -electrons, making them easier to remove and lowering the ionization energy.

Why other options are incorrect:

- **Option A:** The shielding effect increases down a group due to the addition of complete inner electron shells.
- **Option B:** The atomic radius increases down the group, not remains constant.
- **Option C:** Effective nuclear charge on valence electrons remains roughly constant down a group because added nuclear protons are counterbalanced by inner shielding electrons.

Question #86 Key: (A)CHEMISTRY
03. Chemical Bonding*Both carbon atoms in an ethane molecule ([Formula]) exhibit which type of orbital hybridizati...***CORE CONCEPT & DERIVATION**

The hybridization of a carbon atom is determined by its steric number (the number of σ bonds plus lone pairs).

Formula / Rule / Reaction:

$$\text{Steric Number} = 4 \sigma\text{-bonds} + 0 \text{ lone pairs} \Rightarrow \text{sp}^3 \text{ hybridization}$$

Solution:

- In ethane ($\text{CH}_3 - \text{CH}_3$), each carbon forms three single σ bonds to hydrogen atoms and one σ bond to the adjacent carbon atom.
- This produces a tetrahedral geometry with bond angles of approximately 109.5° , characteristic of sp^3 hybridization.

Why other options are incorrect:

- **Option B:** sp^2 hybridization occurs in alkenes (like ethene, C_2H_4) with trigonal planar geometry and one π bond.
- **Option C:** sp hybridization occurs in alkynes (like ethyne, C_2H_2) with linear geometry and two π bonds.
- **Option D:** sp^3d hybridization involves d -orbitals and expanded octets, which second-period carbon cannot form.

Question #87 Key: (D)

CHEMISTRY
06. Solids

The primary type of chemical bonding holding zinc atoms together in solid zinc metal is:

CORE CONCEPT & DERIVATION

Metals consist of a regular crystalline lattice of positive metal cations surrounded by a shared sea of delocalized electrons.

Formula / Rule / Reaction:



Solution:

- Zinc is a d-block metallic element.
- Its crystal lattice consists of positive Zn^{2+} cores held together by electrostatic attraction to a shared pool of delocalized valence 4s electrons (metallic bonding).

Why other options are incorrect:

- **Option A:** Ionic bonding requires electron transfer between a metal cation and a non-metal anion.
- **Option B:** Covalent bonding involves localized electron-pair sharing between non-metal atoms.
- **Option C:** Coordinate covalent bonding requires one atom to donate both electrons in a shared pair to an electron-deficient acceptor.

Question #89 Key: (D)

CHEMISTRY
11. S & P Block Elements

Which of the following periodic properties decreases progressively down Group IIA (alkaline ear...

CORE CONCEPT & DERIVATION

Ionization energy measures the energy required to remove the most loosely bound valence electron from an isolated gaseous atom.

Formula / Rule / Reaction:



Solution:

- Down Group IIA, the number of shielding electron shells increases, expanding the atomic radius.
- The valence ns^2 electrons are held less tightly by the nucleus, causing first ionization energy to decrease from beryllium to barium.

Why other options are incorrect:

- **Option A:** Atomic radius increases down Group IIA as new principal energy levels are added.
- **Option B:** Nuclear charge increases down the group as protons are added to the nucleus.
- **Option C:** The shielding effect increases down the group due to the addition of inner electron shells.

Question #88 Key: (B)

CHEMISTRY
11. S & P Block Elements

Which of the following elements is classified as an intrinsic semiconductor?

CORE CONCEPT & DERIVATION

Semiconductors possess an intermediate bandgap (around 1.1 eV) between a filled valence band and an empty conduction band.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Silicon is a Group IVA metalloid with four valence electrons that forms a covalent diamond-cubic crystal lattice.
- Its electrical conductivity increases with temperature, making it the primary material for solid-state semiconductors.

Why other options are incorrect:

- **Option A:** Aluminium is a good metallic conductor with overlapping valence and conduction bands.
- **Option C:** Phosphorus is a non-metal insulator with a large bandgap.
- **Option D:** Magnesium is an alkaline earth metal with high electrical conductivity.

Question #90 Key: (A)CHEMISTRY
11. S & P Block Elements

Which alkali metal forms both a normal oxide and a peroxide when burned in oxygen?

CORE CONCEPT & DERIVATION

The type of oxide formed by alkali metals depends on cation size and its ability to stabilize different oxygen anions via lattice energy.

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

- Sodium forms normal sodium oxide (Na_2O) in a limited supply of oxygen.
- In excess oxygen, it burns with a bright yellow flame to form stable sodium peroxide (Na_2O_2).

Why other options are incorrect:

- **Option B:** Potassium is larger and forms primarily potassium superoxide (KO_2) when burned in air.
- **Option C:** Lithium forms only the normal monoxide (Li_2O) due to its small size and high charge density.
- **Option D:** Caesium is very large and forms caesium superoxide (CsO_2).

Question #91 Key: (C)CHEMISTRY
12. Transition Elements

Which first-row transition metal element does NOT exhibit variable oxidation states in its comp...

CORE CONCEPT & DERIVATION

Variable oxidation states in transition elements arise from the participation of both $n s$ and $(n - 1) d$ electrons with similar energy levels.

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

- Zinc loses both of its $4s$ valence electrons to form Zn^{2+} .
- The remaining $3d^{10}$ subshell is completely filled, highly stable, and does not participate in chemical bonding, so zinc exhibits only the +2 oxidation state.

Why other options are incorrect:

- **Option A:** Copper exhibits variable oxidation states of +1 (Cu_2O) and +2 (CuO).
- **Option B:** Scandium exhibits the +3 state and is considered by some definitions a non-variable transition metal, but Zinc is the classic d-block element with a single +2 state.
- **Option D:** Chromium shows multiple oxidation states ranging from +2 to +6 (such as Cr^{3+} and $\text{Cr}_2\text{O}_7^{2-}$).

Question #92 Key: (D)CHEMISTRY
12. Transition Elements

In the first transition metal series (3d series), the cohesive binding energy increases progressively...

CORE CONCEPT & DERIVATION

Metallic binding energy in transition elements depends on the number of unpaired electrons available in the $(n-1)d$ and ns subshells to form interatomic covalent bonds.

Formula / Rule / Reaction:

$$\text{Binding Energy} \propto \text{Number of Unpaired } d\text{-Electrons}$$

Solution:

- Moving from left to right, the number of unpaired electrons increases from Scandium up to Vanadium (Group VB) and Chromium (Group VIB, with configuration $3d^5 4s^1$).
- Beyond Group VIB, electron pairing in the d -subshell reduces the number of unpaired electrons, causing binding energy and melting points to decrease toward Group IIB.

Why other options are incorrect:

- **Option A:** Group IIB (Zinc group) has fully paired $d^{10} s^2$ configurations, giving it the lowest binding energy and melting point in the series.
- **Option B:** Group IVB (Titanium group) has only two unpaired d -electrons, with binding energy still on the rising portion of the curve.
- **Option C:** Group IIIB (Scandium group) has only one d -electron and relatively weak cohesive binding.

Question #93 Key: (A)CHEMISTRY
13. Fundamental Principles of Organic Chemistry

Homocyclic (carbocyclic) organic compounds are subdivided into which two primary structural classes...

CORE CONCEPT & DERIVATION

Homocyclic compounds contain rings made up entirely of carbon atoms, which are classified based on electronic structure and chemical behavior.

Formula / Rule / Reaction:

Homocyclic $\rightarrow$ Alicyclic (aliphatic rings) and Aromatic (Hückel's $4n + 2\pi$ system)

Solution:

- Alicyclic compounds are ring systems that behave like aliphatic hydrocarbons (such as cyclohexane and cyclopentane).
- Aromatic compounds contain conjugated cyclic systems that follow Hückel's rule (such as benzene, toluene, and naphthalene).

Why other options are incorrect:

- **Option B:** Open chain (aliphatic) and branched chain compounds are acyclic, not cyclic.
- **Option C:** Heterocyclic compounds contain non-carbon heteroatoms (such as N, O, or S) in the ring, so they are not homocyclic.
- **Option D:** Saturated and unsaturated acyclic compounds are open-chain hydrocarbons.

Question #94 Key: (C)

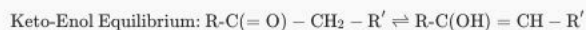
CHEMISTRY
13. Fundamental Principles of Organic Chemistry

The type of constitutional isomerism arising from the dynamic migration of a hydrogen atom (pro...)

CORE CONCEPT & DERIVATION

Tautomers are structural isomers that interconvert rapidly via the migration of a mobile atom (typically hydrogen) accompanied by a shift in double-bond positions.

Formula / Rule / Reaction:



Solution:

- Tautomerism is a special form of functional isomerism where two interconvertible structural forms exist in dynamic chemical equilibrium.
- The most common example is keto-enol tautomerism in carbonyl compounds with α -hydrogens.

Why other options are incorrect:

- **Option A:** Chain isomerism involves different arrangements of the carbon skeleton without dynamic proton transfer.
- **Option B:** Metamerism arises from unequal distribution of carbon atoms on either side of a shared functional heteroatom.
- **Option D:** Position isomerism involves differences in the position of a substituent or functional group on the same carbon chain.

Question #95 Key: (A)

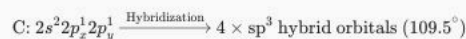
CHEMISTRY
03. Chemical Bonding

In saturated alkanes, each carbon atom exhibits which hybridization state and geometry?

CORE CONCEPT & DERIVATION

Carbon forms four equivalent covalent bonds in saturated alkanes through hybridizing its single $2s$ and three $2p$ valence orbitals.

Formula / Rule / Reaction:



Solution:

- In alkanes (general formula $\text{C}_n\text{H}_{2n+2}$), every carbon atom forms four single σ bonds.
- This produces four sp^3 hybrid orbitals pointing toward the corners of a regular tetrahedron with bond angles of 109.5° .

Why other options are incorrect:

- **Option B:** sp hybridization occurs in alkynes with linear geometry and 180° bond angles.
- **Option C:** sp^2 hybridization occurs in alkenes with trigonal planar geometry and 120° bond angles.
- **Option D:** dsp^2 hybridization occurs in transition metal complexes (such as $[\text{PtCl}_4]^{2-}$), not in organic alkanes.

Question #96 Key: (B)

CHEMISTRY
01. Stoichiometry

For the stoichiometric reaction [Formula], how many moles of [Formula] are required to produce...

CORE CONCEPT & DERIVATION

Stoichiometric calculations convert moles of product to moles of required reactant using mole ratios from the balanced chemical equation.

Formula / Rule / Reaction:



Solution:

- From the balanced equation, 2 moles of NH_3 are produced from 1 mole of N_2 :
- Moles of $\text{N}_2 = 4.0 \text{ mol } \text{NH}_3 \times \left(\frac{1 \text{ mol } \text{N}_2}{2 \text{ mol } \text{NH}_3} \right) = 2.0 \text{ moles of } \text{N}_2$

Why other options are incorrect:

- **Option A:** 4.0 moles of N_2 would produce 8.0 moles of NH_3 .
- **Option C:** 3.0 moles corresponds to the stoichiometric requirement of hydrogen (H_2) for 2 moles of NH_3 , not N_2 .
- **Option D:** 1.0 mole of N_2 produces only 2.0 moles of NH_3 .

Question #97 Key: (C)

CHEMISTRY
01. Stoichiometry

According to the reaction [Formula], how many grams of [Formula] are completely consumed by re...

CORE CONCEPT & DERIVATION

Mass-mass stoichiometry converts reactant mass to moles, applies the molar ratio, and converts the resulting moles back to mass.

Formula / Rule / Reaction:

$$n = \frac{\text{Mass}}{\text{Molar Mass}}, \quad \text{Molar Masses: Al} = 27.0 \text{ g/mol}, \text{ O}_2 = 32.0 \text{ g/mol}$$

Solution:

- Calculate moles of Al:

$$n_{\text{Al}} = \frac{27.0 \text{ g}}{27.0 \text{ g/mol}} = 1.0 \text{ mole of Al}$$

- From the balanced equation, 4 moles of Al react with 3 moles of O₂:

$$n_{\text{O}_2} = 1.0 \text{ mol Al} \times \left(\frac{3 \text{ mol O}_2}{4 \text{ mol Al}} \right) = 0.75 \text{ moles of O}_2$$

- Calculate mass of O₂:

$$\text{Mass} = 0.75 \text{ mol} \times 32.0 \text{ g/mol} = 24.0 \text{ g}$$

Why other options are incorrect:

- Option A:** 8.0 g corresponds to 0.25 moles of O₂, which is insufficient for 1.0 mole of Al.
- Option B:** 16.0 g corresponds to 0.50 moles of O₂.
- Option D:** 32.0 g corresponds to 1.0 mole of O₂, which would require 36.0 g of Al.

Question #98 Key: (B)

CHEMISTRY
02. Atomic Structure

The principal quantum number, which designates the primary energy shell and relative distance o...

CORE CONCEPT & DERIVATION

Quantum numbers specify the energy, angular momentum, spatial orientation, and intrinsic spin of electrons in an atom.

Formula / Rule / Reaction:

$$n \in \{1, 2, 3, 4, \dots\} \implies \text{Energy Shells: K, L, M, N, } \dots$$

Solution:

- The principal quantum number is designated by n .
- It determines the main energy level of the electron and the effective size of the electron cloud.

Why other options are incorrect:

- Option A:** m (or m_l) denotes the magnetic quantum number, which specifies orbital spatial orientation.
- Option C:** s (or m_s) denotes the spin quantum number ($\pm 1/2$).
- Option D:** l denotes the azimuthal (orbital angular momentum) quantum number, which defines subshell shape.

Question #99 Key: (B)

CHEMISTRY
02. Atomic Structure

The geometric shape and angular momentum of an atomic orbital subshell are determined by which ...

CORE CONCEPT & DERIVATION

The azimuthal quantum number defines the orbital angular momentum and the spatial geometric shape of atomic subshells.

Formula / Rule / Reaction:

$$l = 0 \text{ (s, spherical)}, \quad l = 1 \text{ (p, dumbbell)}, \quad l = 2 \text{ (d, double dumbbell)}, \quad l = 3 \text{ (f, complex)}$$

Solution:

- The azimuthal quantum number l takes integral values from 0 up to $n - 1$.
- It specifies the shape of the electron probability distribution (the subshell).

Why other options are incorrect:

- Option A:** The principal quantum number n determines the primary energy level and radial size of the orbital.
- Option C:** The magnetic quantum number m_l determines the three-dimensional spatial orientation of the orbital in a magnetic field.
- Option D:** The spin quantum number m_s specifies the intrinsic spin angular momentum of the electron.

Question #100 Key: (C)

CHEMISTRY
02. Atomic Structure

The rule stating that in degenerate orbitals, electrons enter singly with parallel spins before...

CORE CONCEPT & DERIVATION

Electron configurations in open subshells minimize inter-electronic repulsion by distributing electrons among degenerate orbitals.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Hund's rule of maximum multiplicity states that for degenerate orbitals (such as the three *p* or five *d* orbitals), electrons occupy them singly with parallel spins before any pairing occurs.
- This arrangement minimizes electron-electron repulsion and maximizes exchange energy, yielding a lower, more stable ground-state energy.

Why other options are incorrect:

- Option A:** The Aufbau principle dictates that electrons occupy lower-energy orbitals first before filling higher-energy ones.
- Option B:** The $(n + l)$ rule is an empirical guideline used to predict the relative energy ordering of subshells.
- Option D:** The Pauli exclusion principle states that no two electrons in an atom can share the same four quantum numbers.

Question #101 Key: (C)

CHEMISTRY
01. Stoichiometry

One mole of any chemical substance is defined as the quantity of matter that contains exactly t...

CORE CONCEPT & DERIVATION

The mole is the SI base unit for amount of substance, anchored to the physical mass of the carbon-12 nuclide.

Formula / Rule / Reaction:

$$1 \text{ mole} = 6.02214076 \times 10^{23} \text{ particles} \equiv \text{Atoms in exactly } 0.012 \text{ kg of } ^{12}\text{C}$$

Solution:

- The standard historical definition establishes that one mole contains Avogadro's number of entities.
- This count equals the number of atoms contained in exactly 12 grams (0.012 kg) of unbound, ground-state carbon-12 isotope.

Why other options are incorrect:

- Option A:** 1.008 g is the atomic mass of hydrogen atoms (H), whereas hydrogen gas exists as diatomic molecules (H_2 , molar mass 2.016 g/mol).
- Option B:** 16.00 g is the molar mass of atomic oxygen (O), whereas molecular oxygen gas is O_2 (32.00 g/mol).
- Option D:** 12.00 g of magnesium represents approximately 0.494 moles of magnesium atoms, not one mole.

Question #102 Key: (B)CHEMISTRY
02. Atomic Structure

According to the Pauli exclusion principle, the maximum number of electrons that can occupy a s...

CORE CONCEPT & DERIVATION

No two electrons within an atom can possess an identical set of all four quantum numbers.

Formula / Rule / Reaction:

$$\text{Capacity of single spatial orbital} = 2 \times (m_s = +\frac{1}{2}, -\frac{1}{2})$$

Solution:

- A spatial orbital is defined by three quantum numbers: principal (n), azimuthal (l), and magnetic (m_l).
- Because the spin quantum number (m_s) has only two permissible values, an individual orbital can hold a maximum of two electrons with anti-parallel spins.

Why other options are incorrect:

- **Option A:** A single orbital can accommodate an additional electron if it currently holds only one unpaired electron.
- **Option C:** Accommodating three electrons would violate the Pauli exclusion principle by forcing two electrons to share the same spin.
- **Option D:** Four electrons would require four distinct spin states, which do not exist for spin-1/2 fermions.

Question #103 Key: (D)CHEMISTRY
04. Gases

Atmospheric air is a homogeneous mixture of gases. The gaseous molecules do not settle toward t...

CORE CONCEPT & DERIVATION

Thermal kinetic energy causes continuous random translational motion that counteracts gravitational settling in fluid gases.

Formula / Rule / Reaction:

$$\overline{KE} = \frac{3}{2} k_B T$$

Solution:

- Gas molecules possess high average kinetic velocities (hundreds of meters per second at ambient temperature).
- They undergo constant random collisions that are perfectly elastic, redistributing momentum and maintaining a uniform dispersion against gravity.

Why other options are incorrect:

- **Option A:** Molar mass differences would promote gravitational stratification rather than prevent settling.
- **Option B:** Molecular polarity influences intermolecular attraction, not gravitational suspension.
- **Option C:** Dust particles are macroscopic contaminants that settle over time; they do not suspend gases.

Question #104 Key: (A)

CHEMISTRY
04. Gases

According to the Kinetic Molecular Theory of gases, collisions between gas molecules involve:

CORE CONCEPT & DERIVATION

Collisions between ideal gas molecules are assumed to be perfectly elastic, meaning total mechanical kinetic energy is strictly conserved.

Formula / Rule / Reaction:

$$\sum KE_{\text{before}} = \sum KE_{\text{after}} \quad (Q = 0)$$

Solution:

- While individual colliding molecules can exchange speed and direction, the total kinetic energy of the closed system remains constant.
- No energy is converted into non-conservative heat, sound, or permanent deformation during molecular impacts.

Why other options are incorrect:

- Option B:** Individual molecular momentum vectors change direction during collisions, even though total system momentum is conserved.
- Option C:** Any permanent dissipation would cause gas molecules to lose speed and condense spontaneously into liquids.
- Option D:** Significant loss of kinetic energy would violate the basic tenets of kinetic theory.

Question #105 Key: (C)

CHEMISTRY
04. Gases

According to Charles's law, the volume of an ideal gas theoretically reduces to zero at which t...

CORE CONCEPT & DERIVATION

Charles's law states that at constant pressure, gas volume is directly proportional to absolute thermodynamic temperature.

Formula / Rule / Reaction:

$$V_t = V_0 \left(1 + \frac{t}{273.15} \right) \implies V_t = 0 \text{ at } t = -273.15^\circ\text{C}; (0^\circ\text{K})$$

Solution:

- Extrapolating the linear volume-temperature isobar to zero volume intersects the temperature axis at absolute zero.
- This point corresponds to -273.15°C (0°Kelvin), where all classical molecular translational motion ceases.

Why other options are incorrect:

- Option A:** At -12°C , gases retain significant thermal volume.
- Option B:** 0°C is 273.15°K , the freezing point of water at 1 atm, where gases occupy standard molar volume (22.414 L).
- Option D:** -210°C is above absolute zero; nitrogen remains gaseous until -195.8°C .

Question #106 Key: (B)

CHEMISTRY
05. Liquids

The strongest individual hydrogen bond is formed between molecules of:

CORE CONCEPT & DERIVATION

The electrostatic strength of a hydrogen bond depends on the electronegativity and small ionic radius of the atom bonded to hydrogen.

Formula / Rule / Reaction:

$$\text{Bond Energy: } \text{F-H} \cdots \text{F} (\approx 40 \text{ kJ/mol}) > \text{O-H} \cdots \text{O} (\approx 21 \text{ kJ/mol}) > \text{N-H} \cdots \text{N} (\approx 10 \text{ kJ/mol})$$

Solution:

- Fluorine has the highest electronegativity (4.0) in the periodic table.
- This produces the most polar covalent bond and the highest partial charge density (δ^+ on H, δ^- on F), giving HF the strongest individual hydrogen bond.

Why other options are incorrect:

- Option A:** Sulfur has low electronegativity (2.5) and a large radius; H_2S does not form conventional hydrogen bonds.
- Option C:** Water forms more hydrogen bonds per molecule (4 on average), but each individual $\text{O-H} \cdots \text{O}$ bond is weaker than an individual $\text{F-H} \cdots \text{F}$ bond.
- Option D:** Nitrogen is less electronegative (3.0) than fluorine and oxygen, resulting in weaker hydrogen bonds.

Question #107 Key: (D)CHEMISTRY
05. Liquids

Which of the following liquids possesses the highest surface tension at room temperature?

CORE CONCEPT & DERIVATION

Surface tension arises from unbalanced cohesive intermolecular forces pulling surface molecules toward the bulk interior of a liquid.

Formula / Rule / Reaction:

$$\gamma_{\text{water}} \approx 72.8 \text{ mN/m at } 20^\circ\text{C}$$

Solution:

- Water molecules form an extensive, three-dimensional network of strong intermolecular hydrogen bonds.
- This strong cohesive network creates a high surface tension (approximately 72.8 mN/m), significantly exceeding that of common organic solvents.

Why other options are incorrect:

- **Option A:** Benzene is held only by weak non-polar London dispersion forces ($\gamma \approx 28.9 \text{ mN/m}$).
- **Option B:** Ethyl alcohol exhibits weaker hydrogen bonding than water due to its ethyl group ($\gamma \approx 22.3 \text{ mN/m}$).
- **Option C:** Diethyl ether interacts via weak dipole-dipole forces without hydrogen bonding ($\gamma \approx 17.0 \text{ mN/m}$).

Question #108 Key: (C)CHEMISTRY
05. Liquids

Which of the following hydrocarbons has the highest normal boiling point?

CORE CONCEPT & DERIVATION

In non-polar alkanes, boiling point increases with molecular size and surface area due to stronger London dispersion forces.

Formula / Rule / Reaction:

$$\text{Boiling Point} \propto \text{Polarizability} \propto \text{Molecular Mass} / \text{Chain Length}$$

Solution:

- Decane ($\text{C}_{10}\text{H}_{22}$) has the longest carbon chain, the largest surface contact area, and the highest molecular weight among the options.
- This yields stronger London dispersion forces that require more thermal energy to disrupt, giving it the highest boiling point (approximately 174°C).

Why other options are incorrect:

- **Option A:** Butane is a gas at room temperature (boiling point approximately -0.5°C).
- **Option B:** Hexane has a lower boiling point (approximately 69°C) than decane.
- **Option D:** Propane is a volatile gas (boiling point approximately -42°C).

Question #109 Key: (D)

CHEMISTRY
05. Liquids

Ice floats on the surface of liquid water primarily because:

CORE CONCEPT & DERIVATION

Water displays a density anomaly upon freezing due to the spatial requirements of tetrahedral hydrogen-bonded crystal packing.

Formula / Rule / Reaction:

$$\rho_{\text{ice}} (0.917 \text{ g/cm}^3) < \rho_{\text{water at } 0^\circ\text{C}} (0.9998 \text{ g/cm}^3)$$

Solution:

- When water freezes, each molecule forms four tetrahedral hydrogen bonds with neighboring molecules.
- This locks the molecules into an open hexagonal lattice containing cage-like empty spaces, increasing volume by roughly 9% and reducing its density below that of liquid water.

Why other options are incorrect:

- Option A:** Intramolecular covalent O-H bond lengths remain essentially unchanged between liquid and solid phases.
- Option B:** Ice Ih forms an open hexagonal network, not a compact cubic close-packed lattice.
- Option C:** Hydrogen bonds in ice are more rigid and stable than the transient bonds in liquid water.

Question #110 Key: (A)

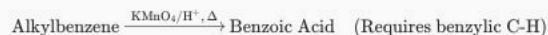
CHEMISTRY
16. Alcohols & Phenols

Which of the following aromatic hydrocarbons is resistant to oxidation by standard oxidizing agents...

CORE CONCEPT & DERIVATION

The delocalized aromatic π -electron sextet provides stability that resists direct ring oxidation, whereas alkyl side-chains with benzylic hydrogens oxidize readily.

Formula / Rule / Reaction:



Solution:

- Benzene lacks an alkyl side chain and has no benzylic hydrogens; its resonance stabilization energy (150.5 kJ/mol) resists strong oxidizing agents like hot alkaline or acidic KMnO_4 .
- Substituted alkylbenzenes (toluene, ethylbenzene, xylene) are readily oxidized to benzoic acid because they possess benzylic C-H bonds.

Why other options are incorrect:

- Option B:** Toluene is oxidized by acidified KMnO_4 to benzoic acid.
- Option C:** Ethylbenzene undergoes side-chain degradation to form benzoic acid.
- Option D:** o-Xylene is oxidized to phthalic acid.

Question #111 Key: (D)

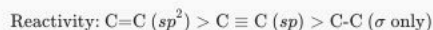
CHEMISTRY
14. Hydrocarbons

The correct order of reactivity of hydrocarbons towards electrophilic addition reactions is:

CORE CONCEPT & DERIVATION

Electrophilic addition rates depend on the availability of π -electrons to attack an incoming electrophile and the stability of the carbocation intermediate.

Formula / Rule / Reaction:



Solution:

- Alkenes possess loosely held π -electrons extending above and below the sp^2 plane, and their attack yields stable alkyl carbocations.
- Alkynes have sp -hybridized carbons that hold π -electrons more tightly, and electrophilic addition forms less stable vinylic carbocations, making them less reactive than alkenes.
- Alkanes possess only strong σ bonds and undergo substitution rather than addition.

Why other options are incorrect:

- Option A:** Incorrectly places unreactive saturated alkanes as the most reactive.
- Option B:** Places non-reactive alkanes ahead of unsaturated alkynes.
- Option C:** Incorrectly ranks alkynes ahead of alkenes.

Question #112 Key: (D)

CHEMISTRY
11. S & P Block Elements

The reactivity order of halogen acids (hydrogen halides) towards cleavage and acidic strength is...

CORE CONCEPT & DERIVATION

The acidic strength and reaction rate of hydrogen halides depend on the H-X covalent bond dissociation energy rather than bond polarity.

Formula / Rule / Reaction:



Solution:

- Down Group VIIA, halide radius increases from fluorine to iodine, lengthening and weakening the H-X bond.
- Because the H-I bond is the weakest and easiest to cleave heterolytically, HI is the strongest acid and most reactive halogen acid.

Why other options are incorrect:

- Option A:** Reverses the trend by relying on electronegativity rather than bond dissociation energy.
- Option B:** Incorrectly places HBr ahead of HI.
- Option C:** Incorrectly ranks HCl ahead of HBr and HI.

Question #113 Key: (A)

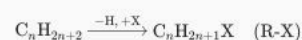
CHEMISTRY
14. Hydrocarbons

Alkyl halides (haloalkanes) are formally considered the mono-halogen derivatives of:

CORE CONCEPT & DERIVATION

Haloalkanes are derived from parent saturated hydrocarbons by replacing one or more hydrogen atoms with halogen atoms.

Formula / Rule / Reaction:



Solution:

- When a single hydrogen atom on an alkane (R-H) is replaced by a halogen atom (X = F, Cl, Br, I), a mono-haloalkane or alkyl halide (R-X) is formed.

Why other options are incorrect:

- Option B:** Halogen derivatives of alkenes are haloalkenes or alkenyl halides (such as vinyl chloride).
- Option C:** Halogen derivatives of alkynes are haloalkynes (such as bromoethyne).
- Option D:** Alcohols are hydroxy derivatives of alkanes, not the parent hydrocarbons of alkyl halides.

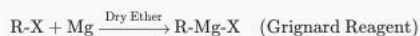
Question #114 Key: (D)

CHEMISTRY
15. Alkyl Halides

A Grignard reagent is synthesized by reacting an alkyl halide in dry ether with:

CORE CONCEPT & DERIVATION

Organomagnesium halides are prepared by inserting magnesium into the carbon-halogen bond of an alkyl halide in an anhydrous solvent.

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

- Magnesium shavings react with an alkyl halide (R-X) in anhydrous diethyl ether, which stabilizes the resulting organometallic complex through coordination.
- This produces an alkyl magnesium halide (Grignard reagent).

Why other options are incorrect:

- **Option A:** Calcium forms organocalcium compounds with difficulty; they are not Grignard reagents.
- **Option B:** Potassium reacts violently and forms organopotassium reagents.
- **Option C:** Sodium reacts with alkyl halides via the Wurtz reaction to form coupled alkanes (R-R).

Question #115 Key: (A)

CHEMISTRY
16. Alcohols & Phenols

Phenol is readily susceptible to oxidation by oxidizing agents primarily because:

CORE CONCEPT & DERIVATION

The +M resonance donation of the phenolic –OH group increases electron density in the aromatic π -system, making it susceptible to oxidation.

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

- Unlike benzene, phenol is readily oxidized upon exposure to air or chemical oxidants (such as chromic acid).
- The oxygen lone pair donates electron density into the ring, facilitating oxidation to 1,4-benzoquinone (p-benzoquinone).

Why other options are incorrect:

- **Option B:** The hydroxyl group activates the ring toward electrophilic attack; it does not deactivate it.
- **Option C:** The phenolic C-O bond has partial double-bond character due to resonance and is difficult to cleave.
- **Option D:** Phenols oxidize readily to form colored quinones.

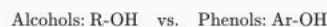
Question #116 Key: (A)

CHEMISTRY
16. Alcohols & Phenols

Both aliphatic alcohols and aromatic phenols contain which characteristic functional group?

CORE CONCEPT & DERIVATION

Alcohols and phenols are classified as hydroxy compounds containing an –OH group bonded to an aliphatic or aromatic carbon, respectively.

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

- Both classes contain the polar hydroxyl group (–OH).
- In alcohols, the –OH is bonded to an sp^3 -hybridized alkyl carbon; in phenols, it is attached directly to an sp^2 -hybridized aromatic benzene ring.

Why other options are incorrect:

- **Option B:** –COOH defines carboxylic acids.
- **Option C:** –CH₂– is a hydrocarbon bridge found in many organic compounds, but it is not the functional group of alcohols.
- **Option D:** –CHO defines aldehydes.

Question #117 Key: (B)CHEMISTRY
18. Carboxylic Acids

Select the correct sequence of relative acidic strength among carboxylic acids, phenols, water,...

CORE CONCEPT & DERIVATION

Relative acidity is governed by the thermodynamic stability and resonance delocalization of the conjugate base anion.

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

- Carboxylate anions are stabilized by resonance between two equivalent electronegative oxygen atoms.
- Phenoxide anions are stabilized by delocalization of charge into the aromatic benzene ring, making phenol more acidic than water.
- Alcohols are weaker acids than water due to the electron-donating inductive effect (+I) of the alkyl group, which destabilizes the alkoxide ion.

Why other options are incorrect:

- Option A:** Incorrectly places water as a stronger acid than phenol.
- Option C:** Incorrectly ranks alcohols as more acidic than phenols and water.
- Option D:** Incorrectly places phenol as weaker than water and aliphatic alcohols.

Question #118 Key: (A)CHEMISTRY
18. Carboxylic Acids

Carboxylic acids react with alcohols in the presence of an inorganic acid catalyst to form:

CORE CONCEPT & DERIVATION

Fischer esterification is an acid-catalyzed condensation between a carboxylic acid and an alcohol that produces an ester and water.

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

- In the presence of concentrated H_2SO_4 , protonation of the carbonyl oxygen activates the carboxylic acid toward nucleophilic attack by the alcohol.
- Subsequent elimination of water forms a carboxylic ester with a characteristic fruity odor.

Why other options are incorrect:

- Option B:** Aldehydes are obtained by the partial oxidation of primary alcohols.
- Option C:** Ketones are obtained by the oxidation of secondary alcohols.
- Option D:** Alkyl halides are formed by reacting alcohols with halogenating agents (like SOCl_2 or PCl_5).

Question #119 Key: (A)CHEMISTRY
17. Aldehydes & Ketones

Catalytic hydrogenation of aldehydes and ketones using molecular hydrogen over a nickel catalysts...

CORE CONCEPT & DERIVATION

The carbonyl group (C=O) undergoes catalytic addition of hydrogen across its π -bond to form alcohols.

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

- Reduction of an aldehyde yields a primary (1°) alcohol.
- Reduction of a ketone yields a secondary (2°) alcohol.

Why other options are incorrect:

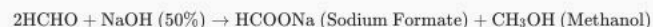
- **Option B:** Carboxylic acids are oxidation products of aldehydes, not reduction products.
- **Option C:** Full reduction to alkanes requires vigorous deoxygenation methods, such as Clemmensen (Zn-Hg/HCl) or Wolff-Kishner (NH₂NH₂/KOH) reductions.
- **Option D:** Acid anhydrides are formed by dehydration of two carboxylic acid molecules.

Question #120 Key: (D)CHEMISTRY
17. Aldehydes & Ketones

When an aldehyde lacking α -hydrogens reacts with 50% concentrated [Formula], it under...

CORE CONCEPT & DERIVATION

Aldehydes lacking α -hydrogen atoms cannot form enolate ions in strong base; instead, they undergo hydride transfer disproportionation.

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

- The Cannizzaro reaction is a redox disproportionation of non-enolizable aldehydes (such as formaldehyde and benzaldehyde).
- One molecule is reduced to an alcohol, while the other is oxidized to a carboxylic acid salt.

Why other options are incorrect:

- **Option A:** The 2,4-DNPH test is a nucleophilic addition-elimination reaction used to detect carbonyl groups by forming colored hydrazones.
- **Option B:** Aldol condensation requires aldehydes or ketones with at least one α -hydrogen to form enolate nucleophiles.
- **Option C:** Clemmensen reduction uses zinc amalgam and concentrated HCl to reduce carbonyl groups to methylene units.

Question #121 Key: (A)CHEMISTRY
19. Macromolecules / Biochemistry

Based on biological function, the iodinated amino acid derivative thyroxine ([Formula]) is cl...

CORE CONCEPT & DERIVATION

Proteins and modified amino acids are categorized functionally as enzymes, structural scaffolds, transport carriers, or chemical signaling hormones.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Thyroxine (tetraiodothyronine) is synthesized by thyroid follicular cells from tyrosine residues in thyroglobulin.
- It functions as an endocrine hormone that regulates basal metabolic rate, body temperature, and cellular oxygen consumption.

Why other options are incorrect:

- Option B:** Structural proteins (such as collagen and keratin) provide mechanical architecture to tissues.
- Option C:** Transport proteins (such as hemoglobin and serum albumin) carry ligands through the bloodstream.
- Option D:** Genetic proteins (such as histones and transcription factors) regulate DNA replication and gene expression.

Question #122 Key: (A)CHEMISTRY
19. Macromolecules / Biochemistry

An enzyme is a natural biological substance that:

CORE CONCEPT & DERIVATION

Enzymes are biological catalysts that increase the rate of biochemical transformations without being permanently consumed.

Formula / Rule / Reaction:

$$\text{Rate} \propto e^{-\Delta G^\ddagger / RT}$$

Solution:

- Enzymes accelerate reaction rates by lowering the activation energy barrier ($\Delta G^\ddagger$).
- This allows metabolic reactions to proceed rapidly under physiological temperatures and neutral pH.

Why other options are incorrect:

- Option B:** Substances that decrease reaction rates are inhibitors, not catalysts.
- Option C:** Catalysts alter reaction kinetics significantly, typically accelerating them by factors of 10^6 to 10^{12} .
- Option D:** Enzymes enable reactions that would otherwise occur too slowly to support life; they do not prevent reactions.

Question #123 Key: (A)PHYSICS
03. Work & Energy

The SI derived unit of kinetic energy is identical to the unit of:

CORE CONCEPT & DERIVATION

Work and energy share the same physical dimensions and derived SI unit, as established by the work-energy theorem.

Formula / Rule / Reaction:

$$[W] = [KE] = M \cdot L^2 \cdot T^{-2} \implies 1 \text{ Joule (J)} = 1 \text{ N} \cdot \text{m} = 1 \text{ kg} \cdot \text{m}^2 \cdot \text{s}^{-2}$$

Solution:

- The work-energy theorem states that the net work done on a body equals its change in kinetic energy ($W_{\text{net}} = \Delta KE$).
- Both physical quantities are measured in joules (J).

Why other options are incorrect:

- Option B:** Power per unit time has dimensions of $W/s = J/s^2$.
- Option C:** Time divided by power has dimensions of s^2/J .
- Option D:** Work per unit time defines power ($P = W/t$), measured in watts (J/s).

Question #124 Key: (D)PHYSICS
04. Rotational & Circular Motion

Which of the following forces provides the necessary centripetal force for an automobile negoti...

CORE CONCEPT & DERIVATION

Circular motion on a flat surface requires a horizontal force directed toward the center of curvature.

Formula / Rule / Reaction:

$$F_c = f_s \leq \mu_s N = \mu_s mg = \frac{mv^2}{r}$$

Solution:

- On a level, unbanked road, the normal force acts vertically and balances the car's weight.
- The only horizontal force directed toward the center of the turn is the lateral static friction (f_s) between the tire tread and the road surface.

Why other options are incorrect:

- Option A:** Weight acts purely downward toward the center of the Earth.
- Option B:** On an unbanked flat road, the normal force is purely vertical, so its horizontal component is zero.
- Option C:** Gravitational force is perpendicular to the horizontal plane of motion and cannot provide centripetal acceleration.

Question #125 Key: (A)PHYSICS
04. Rotational & Circular Motion

How many radians are contained in a plane angle of exactly one degree (1°)?

CORE CONCEPT & DERIVATION

Angular conversion between the sexagesimal system (degrees) and circular measure (radians) is based on a full circle of 2π radians.

Formula / Rule / Reaction:

$$360^\circ = 2\pi \text{ rad} \implies 1^\circ = \frac{\pi}{180} \text{ rad}$$

Solution:

- Calculate the numerical value:
- $1^\circ = \frac{3.14159}{180} \approx 0.017453 \text{ rad}$
- Rounding to three significant figures yields 0.0174 rad.

Why other options are incorrect:

- Option B:** 0.174 rad is off by an order of magnitude (corresponds to approximately 10°).
- Option C:** 1.745 rad corresponds to approximately 100° .
- Option D:** 0.00174 rad is off by an order of magnitude (corresponds to approximately 0.1°).

Question #126 Key: (B)PHYSICS
04. Rotational & Circular Motion

What is the angular velocity of an electric motor shaft rotating at a steady speed of 400 revol...

CORE CONCEPT & DERIVATION

Rotational speed in rpm is converted to angular velocity in radians per second by multiplying by 2π and dividing by 60.

Formula / Rule / Reaction:

$$\omega = N \times \left(\frac{2\pi}{60}\right) = \frac{2\pi N}{60}$$

Solution:

- Substitute $N = 400$ rpm:
- $\omega = \frac{2 \times 3.14159 \times 400}{60} = \frac{800 \times 3.14159}{60} = \frac{2513.27}{60} \approx 41.89 \text{ rad/s}$
- Rounding gives 41.9 rad/s.

Why other options are incorrect:

- **Option A:** 51.2 rad/s corresponds to approximately 489 rpm.
- **Option C:** 45.2 rad/s corresponds to approximately 432 rpm.
- **Option D:** 38.5 rad/s corresponds to approximately 368 rpm.

Question #127 Key: (A)PHYSICS
04. Rotational & Circular Motion

For an object of mass [Formula] moving in a vertical circle of radius [Formula] on a light stri...

CORE CONCEPT & DERIVATION

At the top of a vertical circle, both gravity and string tension act downward to provide the required centripetal force.

Formula / Rule / Reaction:

$$T_{\text{top}} + mg = \frac{mv_{\text{top}}^2}{r} \implies T_{\text{top}} = \frac{mv_{\text{top}}^2}{r} - mg$$

Solution:

- At the minimum critical velocity needed to complete the loop,
 $v_{\text{critical}} = \sqrt{gr}$.

- Substituting this speed:

$$T_{\text{top}} = \frac{m(gr)}{r} - mg = mg - mg = 0$$

- At this critical speed, gravity alone provides the centripetal force and string tension drops to zero.

Why other options are incorrect:

- **Option B:** Tension equals mg if the speed at the top exceeds critical speed ($v = \sqrt{2gr}$).
- **Option C:** $2mg$ occurs at higher rotational speeds.
- **Option D:** $4mg$ is not the minimum tension at the top of the loop.

Question #128 Key: (B)PHYSICS
04. Rotational & Circular Motion

The expression for centripetal force [Formula] in terms of mass [Formula], radius [Formula], ...

CORE CONCEPT & DERIVATION

Centripetal force is the product of mass and centripetal acceleration, which can be expressed in terms of linear or angular velocity.

Formula / Rule / Reaction:

$$a_c = \frac{v^2}{r} = r\omega^2 \implies F_c = ma_c = mr\omega^2$$

Solution:

- Substitute the linear-angular velocity relation $v = r\omega$ into the centripetal force formula:

$$F_c = \frac{m(r\omega)^2}{r} = \frac{mr^2\omega^2}{r} = mr\omega^2$$

Why other options are incorrect:

- Option A:** $mr\omega$ has dimensions of linear momentum ($\text{kg} \cdot \text{m/s}$), not force.
- Option C:** α represents angular acceleration, not angular velocity.
- Option D:** $mr\alpha$ equals tangential force ($F_t = ma_t$), not centripetal force.

Question #129 Key: (D)PHYSICS
04. Rotational & Circular Motion

What is the angular speed in radians per hour of the Earth's daily rotation about its axis?

CORE CONCEPT & DERIVATION

Angular speed is defined as the total angular displacement divided by the elapsed time.

Formula / Rule / Reaction:

$$\omega = \frac{\Delta\theta}{\Delta t}$$

Solution:

- The Earth completes one full rotation (2π radians) in 24 hours:

$$\omega = \frac{2\pi \text{ radians}}{24 \text{ hours}} = \frac{\pi}{12} \text{ rad/h}$$

Why other options are incorrect:

- Option A:** 2π is the total angular displacement in a full 24-hour day.
- Option B:** 4π corresponds to two complete revolutions per hour.
- Option C:** $\pi/6$ rad/h corresponds to a 12-hour rotational period.

Question #130 Key: (A)PHYSICS
05. Waves

The wavelength ([Formula]) of a progressive wave is defined as the:

CORE CONCEPT & DERIVATION

Wavelength is the spatial period of a wave, measured as the distance over which the wave shape repeats.

Formula / Rule / Reaction:

$$\lambda = \frac{v}{f}$$

Solution:

- Wavelength is the distance between any two adjacent points in the same phase of oscillation.
- The simplest reference points are two consecutive crests or two consecutive troughs.

Why other options are incorrect:

- Option B:** The distance between two alternate crests spans two full wavelengths (2λ).
- Option C:** The distance between two alternate troughs is also 2λ .
- Option D:** Two full crests and two full troughs span multiple wavelengths.

Question #131 Key: (A)PHYSICS
05. Waves

Which of the following physical factors does NOT affect the speed of sound in air at constant t ...

CORE CONCEPT & DERIVATION

According to Laplace's formula, the speed of sound in an ideal gas depends on the pressure-to-density ratio, which is constant at a given temperature.

Formula / Rule / Reaction:

$$v = \sqrt{\frac{\gamma P}{\rho}} = \sqrt{\frac{\gamma RT}{M}}$$

Solution:

- By Boyle's law, at constant temperature, pressure is directly proportional to density ($P/\rho = \text{constant}$).
- Any increase in pressure produces a proportional increase in density, leaving the speed of sound unchanged.

Why other options are incorrect:

- **Option B:** Changing density at constant pressure alters sound speed ($v \propto 1/\sqrt{\rho}$).
- **Option C:** Temperature changes sound speed directly ($v \propto \sqrt{T}$).
- **Option D:** The medium's molar mass and heat capacity ratio (γ) determine sound speed.

Question #132 Key: (B)PHYSICS
05. Waves

The maximum displacement of vibrating particles of a medium from their equilibrium position is ...

CORE CONCEPT & DERIVATION

Amplitude measures the magnitude of maximum disturbance in an oscillating medium.

Formula / Rule / Reaction:

$$x(t) = x_0 \sin(\omega t + \phi) \implies \text{Amplitude} = x_0$$

Solution:

- Amplitude is the maximum positive or negative displacement of an oscillating particle from its central mean equilibrium position.
- It is directly related to the energy carried by the wave ($E \propto A^2$).

Why other options are incorrect:

- **Option A:** Frequency is the number of complete oscillations per second.
- **Option C:** Wavelength is the spatial distance between successive in-phase points.
- **Option D:** A crest is the physical peak or point of maximum positive displacement on a transverse wave.

Question #133 Key: (B)PHYSICS
05. Waves

Ultrasonic sound waves are characterized by frequencies exceeding the upper limit of human hear...

CORE CONCEPT & DERIVATION

The human ear detects acoustic frequencies within a nominal audible range of 20 Hz to 20,000 Hz.

Formula / Rule / Reaction:

$$f_{\text{infrasonic}} < 20 \text{ Hz} \leq f_{\text{audible}} \leq 20 \text{ kHz} < f_{\text{ultrasonic}}$$

Solution:

- Frequencies above 20 kHz (20,000 Hz) are termed ultrasonic.
- They cannot be perceived by the human ear but are widely used in medical imaging (ultrasound) and industrial testing.

Why other options are incorrect:

- **Option A:** 20 Hz is the lower threshold of human hearing; frequencies below 20 Hz are infrasonic.
- **Option C:** 200 kHz is ultrasonic, but it is not the threshold defining the lower boundary of ultrasound.
- **Option D:** 2000 kHz (2 MHz) is well within the ultrasonic range used in diagnostic imaging, not the starting boundary.

Question #134 Key: (A)

PHYSICS
05. Waves

The speed of sound in air increases for each 1°C rise in temperature above 0°C by approximate...

CORE CONCEPT & DERIVATION

The speed of sound in air increases with temperature due to the higher kinetic energy and speed of gas molecules.

Formula / Rule / Reaction:

$$v_t \approx v_0 + 0.61 t \quad (v_0 = 332 \text{ m/s at } 0^\circ\text{C})$$

Solution:

- Using a Taylor expansion of $v_t = v_0 \sqrt{1 + t/273.15}$:

$$v_t \approx v_0 \left(1 + \frac{t}{546.3}\right) = 332 + \left(\frac{332}{546.3}\right)t = 332 + 0.61t$$

- Thus, for every 1°C increase, the speed of sound rises by approximately 0.61 m/s .

Why other options are incorrect:

- Option B:** 0.51 m/s is an incorrect numerical coefficient.
- Option C:** 0.41 m/s is lower than the accepted value derived from the gas constant.
- Option D:** 0.31 m/s is roughly half the actual temperature coefficient.

Question #135 Key: (D)

PHYSICS
05. Waves

A continuous, regular, and rhythmic disturbance generated in a medium by the periodic vibration...

CORE CONCEPT & DERIVATION

Waves are classified by the temporal pattern of their source into isolated wave pulses or continuous periodic wave trains.

Formula / Rule / Reaction:

$$y(x, t) = A \sin(kx - \omega t)$$

Solution:

- A single disturbance produces a solitary wave pulse.
- A source executing continuous, regular, simple harmonic vibrations generates a train of periodic waves.

Why other options are incorrect:

- Option A:** Complex waves result from the superposition of multiple harmonic waves with different frequencies.
- Option B:** Stationary (standing) waves require the superposition of two identical waves traveling in opposite directions.
- Option C:** Electromagnetic waves consist of oscillating electric and magnetic fields that do not require a material medium.

Question #136 Key: (C)

PHYSICS
07. Thermodynamics

A thermodynamic process in which the volume of the working substance remains strictly constant ...

CORE CONCEPT & DERIVATION

Thermodynamic processes are named based on the state variable held constant during the state transition.

Formula / Rule / Reaction:

$$\Delta V = 0 \implies W = \int P dV = 0$$

Solution:

- An isochoric (or isometric) process occurs at constant volume.
- Because boundary displacement is zero ($\Delta V = 0$), no pressure-volume work is done ($W = 0$), and all heat added changes the internal energy ($Q = \Delta U$).

Why other options are incorrect:

- Option A:** An isothermal process occurs at constant temperature ($\Delta T = 0$).
- Option B:** An isobaric process occurs at constant pressure ($\Delta P = 0$).
- Option D:** An adiabatic process occurs with no heat transfer into or out of the system ($Q = 0$).

Question #137 Key: (B)PHYSICS
07. Thermodynamics

The conditions for the application of Boyle's law ([Formula]) are satisfied during which ther...

CORE CONCEPT & DERIVATION

Boyle's law states that for a fixed mass of gas, pressure is inversely proportional to volume at constant temperature.

Formula / Rule / Reaction:

$$T = \text{constant} \implies PV = nRT = \text{constant}$$

Solution:

- An isothermal process is defined by constant temperature ($\Delta T = 0$).
- Under this condition, the ideal gas equation simplifies to $PV = \text{constant}$, matching Boyle's law.

Why other options are incorrect:

- **Option A:** In an adiabatic process, temperature changes as the gas expands or compresses ($PV^\gamma = \text{constant}$).
- **Option C:** In an isobaric process, pressure is constant and volume changes with temperature (Charles's law).
- **Option D:** In an isochoric process, volume is constant and pressure changes with temperature (Gay-Lussac's law).

Question #138 Key: (D)PHYSICS
07. Thermodynamics

During an isothermal expansion of an ideal gas, its internal energy:

CORE CONCEPT & DERIVATION

The internal energy of an ideal gas depends solely on its absolute thermodynamic temperature (Joule's law).

Formula / Rule / Reaction:

$$U = \frac{f}{2}nRT \implies \Delta U = nC_v\Delta T$$

Solution:

- In an isothermal process, temperature remains constant ($\Delta T = 0$).
- Because $\Delta T = 0$, the change in internal energy is zero ($\Delta U = 0$), meaning internal energy remains constant throughout the process.

Why other options are incorrect:

- **Option A:** Internal energy decreases during an adiabatic expansion, not an isothermal one.
- **Option B:** Internal energy increases only when temperature increases.
- **Option C:** Total internal energy is a positive quantity determined by absolute temperature in Kelvin; it does not drop to zero.

Question #139 Key: (C)PHYSICS
08. Electrostatics

The electric intensity and electric flux associated with symmetrical continuous charge distribu...

CORE CONCEPT & DERIVATION

Gauss's law relates the total electric flux passing through a closed hypothetical surface to the net enclosed charge.

Formula / Rule / Reaction:

$$\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{enclosed}}}{\epsilon_0}$$

Solution:

- Gauss's law provides a straightforward method for calculating the electric field ($\vec{E}$) around charge distributions with spherical, cylindrical, or planar symmetry.

Why other options are incorrect:

- **Option A:** Ohm's law relates current, potential difference, and resistance in electrical conductors.
- **Option B:** Faraday's law describes electromotive force induced by changing magnetic flux.
- **Option D:** Ampere's law relates magnetic field along a closed loop to the enclosed electric current.

Question #140 Key: (D)PHYSICS
08. Electrostatics

The capacitance of a parallel plate capacitor does NOT depend on the:

CORE CONCEPT & DERIVATION

Capacitance measures a system's ability to store electric charge per unit potential difference, determined by geometry and dielectric material.

Formula / Rule / Reaction:

$$C = \frac{\epsilon_0 \epsilon_r A}{d}$$

Solution:

- Capacitance depends directly on plate area (A), dielectric constant (ϵ_r), and plate separation (d).
- Electrostatic charge resides entirely on the inner facing surfaces of the plates; plate thickness does not affect the electric field or capacitance.

Why other options are incorrect:

- **Option A:** Capacitance is directly proportional to plate area ($C \propto A$).
- **Option B:** A dielectric with higher relative permittivity increases capacitance ($C \propto \epsilon_r$).
- **Option C:** Capacitance is inversely proportional to plate separation ($C \propto 1/d$).

Question #141 Key: (A)PHYSICS
08. Electrostatics

The SI unit of electric potential difference is the:

CORE CONCEPT & DERIVATION

Electric potential difference is the work done per unit charge in moving a test charge between two points in an electric field.

Formula / Rule / Reaction:

$$\Delta V = \frac{W}{q} \implies 1 \text{ Volt (V)} = 1 \text{ Joule per Coulomb (J/C)}$$

Solution:

- The SI unit of potential difference and electromotive force is the volt (V), named in honor of Alessandro Volta.

Why other options are incorrect:

- Option B:** The coulomb (C) is the SI unit of electric charge.
- Option C:** The watt (W) is the SI unit of power (1 J/s).
- Option D:** The electron-volt (eV) is a non-SI unit of energy (1.602×10^{-19} J).

Question #142 Key: (A)PHYSICS
08. Electrostatics

Electric potential at a specific point in an electrostatic field is formally defined as the:

CORE CONCEPT & DERIVATION

Electric potential is a scalar field quantity representing the electrostatic potential energy per unit charge relative to a zero reference at infinity.

Formula / Rule / Reaction:

$$V = \frac{W_{\infty \rightarrow P}}{q_0} = - \int_{\infty}^P \vec{E} \cdot d\vec{r}$$

Solution:

- Electric potential V at point P is the work done by an external agent against electrostatic forces in moving a unit positive test charge from infinity to P without acceleration.

Why other options are incorrect:

- Option B:** Force per unit positive charge defines electric field intensity ($\vec{E} = \vec{F}/q_0$), a vector quantity.
- Option C:** Power per unit charge has dimensions of volts per second, which does not define potential.
- Option D:** Total potential energy is an extensive energy quantity (in joules), not potential (in joules per coulomb).

Question #143 Key: (B)PHYSICS
09. Current Electricity

The ohm-meter ([Formula]) is the derived SI unit of:

CORE CONCEPT & DERIVATION

Resistivity is an intrinsic material property that quantifies how strongly a substance opposes the flow of electric current.

Formula / Rule / Reaction:

$$R = \rho \frac{L}{A} \implies \rho = \frac{RA}{L} = \frac{\Omega \cdot \text{m}^2}{\text{m}} = \Omega \cdot \text{m}$$

Solution:

- Solving for resistivity (ρ) yields units of ohm-meters ($\Omega \cdot \text{m}$).

Why other options are incorrect:

- Option A:** Electrical resistance is measured in ohms (Ω).
- Option C:** Electrical conductance is measured in siemens (S) or reciprocal ohms (Ω^{-1}).
- Option D:** Electrical conductivity ($\sigma = 1/\rho$) is measured in siemens per meter (S/m or $\Omega^{-1} \cdot \text{m}^{-1}$).

Question #144 Key: (A)PHYSICS
08. Electrostatics

One electron-volt (1 eV) of energy is equivalent to exactly how many joules?

CORE CONCEPT & DERIVATION

An electron-volt is the kinetic energy gained or lost by an electron accelerated through an electric potential difference of one volt.

Formula / Rule / Reaction:

$$W = q\Delta V \implies 1 \text{ eV} = (1.60218 \times 10^{-19} \text{ C}) \times (1 \text{ V}) = 1.602 \times 10^{-19} \text{ J}$$

Solution:

- Using $W = qV$, multiplying elementary charge by one volt yields 1.602×10^{-19} J.

Why other options are incorrect:

- Option B:** 16.02×10^{-19} J is incorrect due to a misplaced decimal point (off by a factor of 10).
- Option C:** 1620 J is a macroscopic energy value.
- Option D:** 162.0×10^{-19} J is off by two orders of magnitude.

Question #145 Key: (B)PHYSICS
09. Current Electricity

The electrical resistance of a uniform metallic wire of length [Formula] and uniform cross-sect...

CORE CONCEPT & DERIVATION

Resistance reflects the opposition to electron flow from collisions with lattice ions, governed by conductor geometry.

Formula / Rule / Reaction:

$$R = \rho \frac{L}{A} \Rightarrow R \propto L \text{ and } R \propto \frac{1}{A}$$

Solution:

- A larger cross-sectional area provides more parallel conduction paths for charge carriers, reducing resistance.
- Thus, resistance is inversely proportional to cross-sectional area ($R \propto 1/A$).

Why other options are incorrect:

- **Option A:** Resistance is directly proportional to conductor length ($R \propto L$).
- **Option C:** For metallic conductors, resistance increases with temperature.
- **Option D:** Resistance is directly proportional to material resistivity ($R \propto \rho$).

Question #146 Key: (A)PHYSICS
09. Current Electricity

The commercial electrical billing unit kilowatt-hour ([Formula]) is a unit of:

CORE CONCEPT & DERIVATION

Multiplying a unit of power by a unit of time yields an amount of energy.

Formula / Rule / Reaction:

$$E = P \times t \Rightarrow 1 \text{ kW} \cdot \text{h} = (1000 \text{ W}) \times (3600 \text{ s}) = 3.6 \times 10^6 \text{ J} = 3.6 \text{ MJ}$$

Solution:

- A kilowatt is a unit of power, and an hour is a unit of time.
- Their product represents total work or electrical energy consumed, equivalent to 3.6 megajoules.

Why other options are incorrect:

- **Option B:** Electrical power is the rate of energy consumption, measured in watts or kilowatts, not kilowatt-hours.
- **Option C:** Momentum has units of kilogram-meters per second ($\text{kg} \cdot \text{m/s}$).
- **Option D:** Electrical current is measured in amperes (A).

Question #147 Key: (B)PHYSICS
10. Electromagnetism

The magnetic force exerted on a charged particle moving through a uniform magnetic field is max...

CORE CONCEPT & DERIVATION

The Lorentz magnetic force on a moving charge depends on the cross product of its velocity and the magnetic field.

Formula / Rule / Reaction:

$$F_B = |q|vB \sin \theta \Rightarrow F_{\text{max}} \text{ occurs when } \sin \theta = 1 (\theta = 90^\circ)$$

Solution:

- The magnitude of the magnetic force is proportional to $\sin \theta$.
- The sine function reaches its maximum value of 1 when $\theta = 90^\circ$, so the force is greatest when the velocity is perpendicular to the magnetic field.

Why other options are incorrect:

- **Option A:** At 60° , $\sin 60^\circ = \frac{\sqrt{3}}{2} \approx 0.866$, yielding sub-maximal force.
- **Option C:** At 0° (parallel motion), $\sin 0^\circ = 0$, and the magnetic force is zero.
- **Option D:** At 45° , $\sin 45^\circ = \frac{1}{\sqrt{2}} \approx 0.707$.

Question #148 Key: (C)PHYSICS
10. Electromagnetism

When a charged particle enters a uniform magnetic field with its velocity oriented parallel to ...

CORE CONCEPT & DERIVATION

A magnetic field exerts a deflecting force only on velocity components perpendicular to the field lines.

Formula / Rule / Reaction:

$$F_B = qvB \sin(0^\circ) = 0 \Rightarrow a = 0$$

Solution:

- When velocity is parallel to the magnetic field, the angle $\theta = 0^\circ$.
- Because $\sin 0^\circ = 0$, the magnetic force is zero, and the particle continues in a straight line at constant velocity.

Why other options are incorrect:

- **Option A:** Deflection requires a non-zero magnetic force, which is absent here.
- **Option B:** No sideways deflecting force acts on the charge.
- **Option D:** Helical motion requires a velocity component perpendicular to the field ($0^\circ < \theta < 90^\circ$).

Question #149 Key: (A)PHYSICS
10. Electromagnetism

The SI unit of magnetic induction (magnetic flux density) is the tesla (T), which is defined as...

CORE CONCEPT & DERIVATION

Magnetic flux density B is defined from the magnetic force on a current-carrying conductor or moving charge.

Formula / Rule / Reaction:

$$F = ILB \sin \theta \implies B = \frac{F}{IL} = \frac{N}{A \cdot m} = N \cdot A^{-1} \cdot m^{-1}$$

Solution:

- One tesla is the magnetic flux density that exerts a force of one newton on a one-meter length of conductor carrying a current of one ampere perpendicular to the field.
- This gives base units of $N \cdot A^{-1} \cdot m^{-1}$.

Why other options are incorrect:

- Option B:** $N \cdot m \cdot A^{-1}$ has meters in the numerator rather than the denominator.
- Option C:** Has an inverted newton dimension.
- Option D:** Lacks inverse dimensions for current and length.

Question #150 Key: (A)PHYSICS
02. Force & Motion

In an isolated mechanical system, two balls undergo an elastic collision. Which statement is ph...

CORE CONCEPT & DERIVATION

An elastic collision is defined by the simultaneous conservation of total linear momentum and total kinetic energy.

Formula / Rule / Reaction:

$$\sum \vec{p}_i = \sum \vec{p}_f \quad \text{and} \quad \sum KE_i = \sum KE_f$$

Solution:

- In a perfectly elastic collision, no kinetic energy is converted into heat, sound, or permanent deformation.
- Therefore, total kinetic energy after the collision equals total kinetic energy before the collision.

Why other options are incorrect:

- Option B:** Linear momentum is conserved in all collisions in an isolated system.
- Option C:** Kinetic energy is not conserved in inelastic collisions, but it is conserved in elastic collisions.
- Option D:** Equating momentum to kinetic energy is dimensionally invalid.

Question #151 Key: (C)PHYSICS
02. Force & Motion

The gradient (slope) of a velocity-time graph represents which physical quantity?

CORE CONCEPT & DERIVATION

The first derivative of velocity with respect to time yields the rate of change of velocity, defined as acceleration.

Formula / Rule / Reaction:

$$\text{Slope} = \frac{\Delta v}{\Delta t} = \frac{dv}{dt} = a$$

Solution:

- On a velocity-time graph, the vertical axis plots velocity and the horizontal axis plots time.
- The gradient of the tangent at any point yields the instantaneous linear acceleration of the moving body.

Why other options are incorrect:

- Option A:** Total displacement is determined by the area under the velocity-time graph, not its gradient.
- Option B:** Net force is the product of mass and acceleration ($F = ma$), requiring mass to be known.
- Option D:** Speed is the scalar magnitude of velocity, not the slope of the curve.

Question #153 Key: (B)PHYSICS
02. Force & Motion

Two automobiles travel along a straight highway in opposite directions with constant speeds of ...

CORE CONCEPT & DERIVATION

The relative velocity between two bodies moving along the same line is obtained by vector subtraction of their individual velocities.

Formula / Rule / Reaction:

$$\vec{v}_{\text{rel}} = \vec{v}_1 - \vec{v}_2 \implies v_{\text{rel}} = v_1 - (-v_2) = v_1 + v_2$$

Solution:

- Because the cars travel in opposite directions, taking one direction as positive gives $v_1 = +70 \text{ km/h}$ and $v_2 = -60 \text{ km/h}$.
- The relative speed is the magnitude of the difference: $v_{\text{rel}} = 70 - (-60) = 70 + 60 = 130 \text{ km/h}$.

Why other options are incorrect:

- Option A:** 10 km/h is the relative speed if both vehicles were moving in the same direction ($70 - 60$).
- Option C:** 65 km/h represents the numerical average of the two speeds.
- Option D:** 5 km/h is an arbitrary value with no physical basis.

Question #152 Key: (B)PHYSICS
02. Force & Motion

For a projectile launched with a given initial speed, the horizontal ranges are identical for w...

CORE CONCEPT & DERIVATION

The horizontal range of a projectile launched on level ground depends on $\sin(2\theta)$, yielding identical values for complementary angles.

Formula / Rule / Reaction:

$$R = \frac{v_0^2 \sin(2\theta)}{g} \implies R(\theta) = R(90^\circ - \theta)$$

Solution:

- The trigonometric identity $\sin(2(90^\circ - \theta)) = \sin(180^\circ - 2\theta) = \sin(2\theta)$ dictates that complementary angles produce the same range.
- Because $60^\circ + 30^\circ = 90^\circ$, both angles yield $\sin(2 \times 60^\circ) = \sin(120^\circ) = \frac{\sqrt{3}}{2}$ and $\sin(2 \times 30^\circ) = \sin(60^\circ) = \frac{\sqrt{3}}{2}$.

Why other options are incorrect:

- Option A:** 20° and 60° sum to 80° , so their ranges are unequal.
- Option C:** 40° and 60° sum to 100° , not 90° .
- Option D:** 25° and 55° sum to 80° , not 90° .

Question #154 Key: (D)

PHYSICS
02. Force & Motion

Two bodies of equal mass [Formula] undergo a one-dimensional head-on elastic collision. Their v...

CORE CONCEPT & DERIVATION

In a perfectly elastic one-dimensional collision between two bodies of identical mass, the colliding bodies exchange their velocities completely.

Formula / Rule / Reaction:

$$v_1' = \left(\frac{m_1 - m_2}{m_1 + m_2} \right) v_1 + \left(\frac{2m_2}{m_1 + m_2} \right) v_2$$

Solution:

- Set $m_1 = m_2 = m$ in the elastic collision equations:

$$v_1' = \left(\frac{m - m}{2m} \right) v_1 + \left(\frac{2m}{2m} \right) v_2 = 0 + v_2 = v_2$$

$$v_2' = \left(\frac{2m}{2m} \right) v_1 + \left(\frac{m - m}{2m} \right) v_2 = v_1 + 0 = v_1$$

- Thus, the bodies simply swap their initial velocities.

Why other options are incorrect:

- Option A:** Both bodies cannot come to rest simultaneously without violating conservation of momentum.
- Option B:** The second body comes to rest only if the first body was initially at rest ($v_1 = 0$).
- Option C:** Velocities remain unchanged only if no physical collision occurs.

Question #155 Key: (D)

PHYSICS
02. Force & Motion

The launch angle of a projectile for which its maximum height equals its horizontal range is ap...

CORE CONCEPT & DERIVATION

Setting the kinematic formula for maximum vertical height equal to horizontal range determines the required projection angle.

Formula / Rule / Reaction:

$$H = \frac{v_0^2 \sin^2 \theta}{2g}, \quad R = \frac{v_0^2 \sin(2\theta)}{g} = \frac{2v_0^2 \sin \theta \cos \theta}{g}$$

Solution:

- Set $H = R$:

$$\frac{v_0^2 \sin^2 \theta}{2g} = \frac{2v_0^2 \sin \theta \cos \theta}{g}$$

- Simplify by canceling common terms:

$$\frac{\sin \theta}{2} = 2 \cos \theta \implies \frac{\sin \theta}{\cos \theta} = 4 \implies \tan \theta = 4$$

$$\theta = \arctan(4) \approx 75.96^\circ \approx 76^\circ$$

Why other options are incorrect:

- Option A:** 86° yields a maximum height far larger than its range ($\tan 86^\circ \approx 14.3$).
- Option B:** 46° yields $\tan 46^\circ \approx 1.035$, where height is approximately one-fourth of the range.
- Option C:** 66° yields $\tan 66^\circ \approx 2.25$.

Question #156 Key: (B)PHYSICS
02. Force & Motion

The slope of a distance-time graph can never be:

CORE CONCEPT & DERIVATION

Distance is a cumulative scalar quantity defined as the total path length traveled, which can never decrease with time.

Formula / Rule / Reaction:

$$\text{Speed} = \frac{\Delta s}{\Delta t} \geq 0 \quad (\Delta s \geq 0, \Delta t > 0)$$

Solution:

- Because total path distance cannot decrease, Δs is always greater than or equal to zero.
- Consequently, the gradient (speed) must be zero or positive; it can never be negative.

Why other options are incorrect:

- Option A:** A positive slope corresponds to normal forward motion with non-zero speed.
- Option C:** A slope of zero represents a stationary object at rest.
- Option D:** A constant slope represents uniform motion with constant speed.

Question #157 Key: (D)PHYSICS
02. Force & Motion

What are the horizontal and vertical velocity components of a projectile at the apex of its tra...

CORE CONCEPT & DERIVATION

In ideal projectile motion, horizontal motion occurs at constant velocity while vertical motion is subject to constant gravitational acceleration.

Formula / Rule / Reaction:

$$a_x = 0 \implies v_x(t) = v_0 \cos \theta = \text{constant}, \quad v_y(t_{\text{apex}}) = 0$$

Solution:

- In the absence of air resistance, no horizontal forces act on the projectile, so its horizontal velocity component remains constant throughout flight.
- At the apex of the parabolic path, vertical upward motion momentarily ceases before the projectile begins to fall, so $v_y = 0$.

Why other options are incorrect:

- Option A:** The horizontal velocity component v_x does not drop to zero; if it did, the projectile would fall straight down.
- Option B:** v_x is non-zero, and v_y changes continuously under gravity rather than remaining constant.
- Option C:** v_y is zero at the peak, not a non-zero constant.

Question #158 Key: (A)PHYSICS
03. Work & Energy

The conventional engineering unit of power in the British gravitational system is the:

CORE CONCEPT & DERIVATION

Power units in traditional engineering systems are defined by foot-pounds of work performed per unit time.

Formula / Rule / Reaction:

$$1 \text{ hp} = 550 \text{ ft} \cdot \text{lb/s} = 33,000 \text{ ft} \cdot \text{lb/min} \approx 745.7 \text{ W}$$

Solution:

- James Watt standardized the horsepower (hp) in the British engineering system.
- It is defined as the ability to perform 550 foot-pounds of mechanical work per second.

Why other options are incorrect:

- Option B:** The watt is the SI unit of power (1 J/s).
- Option C:** Joule per second is the definition of the SI watt.
- Option D:** Joule-second is the unit of action and Planck's constant, not power.

Question #159 Key: (D)PHYSICS
03. Work & Energy

Mechanical work done by a force is negative when the angle [Formula] between the force vector a...

CORE CONCEPT & DERIVATION

Work is the scalar dot product of the force and displacement vectors, whose sign depends on $\cos \theta$.

Formula / Rule / Reaction:

$$W = \vec{F} \cdot \vec{d} = Fd \cos \theta$$

Solution:

- Work is negative when the angle lies between 90° and 180° ($\cos \theta < 0$).
- At $\theta = 180^\circ$, $\cos 180^\circ = -1$, yielding the maximum negative work ($W = -Fd$), as seen with kinetic friction.

Why other options are incorrect:

- Option A:** At 0° , $\cos 0^\circ = +1$, yielding maximum positive work.
- Option B:** At 45° , $\cos 45^\circ = +0.707$, yielding positive work.
- Option C:** At 60° , $\cos 60^\circ = +0.5$, yielding positive work.

Question #160 Key: (C)PHYSICS
03. Work & Energy

A power consumption rate of [Formula] is equivalent to:

CORE CONCEPT & DERIVATION

Mechanical power is defined as the rate at which work is done over time.

Formula / Rule / Reaction:

$$P = \frac{W}{t} = \frac{F \cdot d}{t} \Rightarrow 1 \text{ N} \cdot \text{m} \cdot \text{s}^{-1} = 1 \text{ J} \cdot \text{s}^{-1} = 1 \text{ Watt (W)}$$

Solution:

- Because one newton-meter equals one joule of work ($1 \text{ N} \cdot \text{m} = 1 \text{ J}$), a rate of $1 \text{ N} \cdot \text{m/s}$ equals 1 J/s , which is 1 Watt.

Why other options are incorrect:

- Option A:** A kilowatt-hour is a unit of energy equal to $3.6 \times 10^6 \text{ J}$, not a unit of power.
- Option B:** Joule-seconds have units of angular momentum.
- Option D:** $\text{J} \cdot \text{s}^{-2}$ represents the time rate of change of power.

Question #161 Key: (C)PHYSICS
03. Work & Energy

In energy transformations involving motion against a frictional force [Formula] across a distan...

CORE CONCEPT & DERIVATION

Work done against a resistive force equals the product of the magnitude of that force and the distance moved along its line of action.

Formula / Rule / Reaction:

$$W_f = f \times d = fh$$

Solution:

- When an object moves a distance h against a frictional force f , the mechanical work converted into thermal energy is the product fh .

Why other options are incorrect:

- Option A:** Summing force and distance is dimensionally invalid.
- Option B:** Subtracting distance from force is dimensionally invalid.
- Option D:** Dividing force by distance yields a spring constant (N/m), not work.

Question #162 Key: (B)PHYSICS
03. Work & Energy

A car of mass 800 kg accelerates uniformly along a straight track from [Formula] to [Formula]....

CORE CONCEPT & DERIVATION

The change in kinetic energy is calculated from the difference between the final and initial kinetic energies.

Formula / Rule / Reaction:

$$\Delta KE = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = \frac{1}{2}m(v_f^2 - v_i^2)$$

Solution:

- Substitute the given values ($m = 800 \text{ kg}$, $v_i = 20 \text{ m/s}$, $v_f = 30 \text{ m/s}$):

$$\Delta KE = \frac{1}{2}(800)(30^2 - 20^2) = 400 \times (900 - 400)$$

$$\Delta KE = 400 \times 500 = 200,000 \text{ J} = 200 \text{ kJ}$$

Why other options are incorrect:

- Option A:** 2 J is an incorrect calculation that ignores the mass scale.
- Option C:** 200 J ignores the kilo prefix (off by a factor of 1,000).
- Option D:** 2 kJ is off by two orders of magnitude.

Question #163 Key: (C)PHYSICS
11. Electromagnetic Induction

In Fleming's right-hand rule for induced electromotive force, the middle finger (second finger)...

CORE CONCEPT & DERIVATION

Fleming's right-hand rule gives the direction of induced current when a straight conductor moves through a magnetic field.

Formula / Rule / Reaction:

Thumb: Motion ($\vec{v}$), Forefinger: Field ($\vec{B}$), Middle Finger: Induced Current ($\vec{I}$)

Solution:

- Holding the thumb, forefinger, and middle finger mutually at right angles:
- The thumb points in the direction of conductor motion.
- The forefinger (first finger) points in the direction of the magnetic field (North to South).
- The middle finger (second finger) indicates the direction of the induced current.

Why other options are incorrect:

- **Option A:** Motion and mechanical thrust are indicated by the thumb.
- **Option B:** The magnetic field is indicated by the forefinger.
- **Option D:** Conductor acceleration aligns with motion, indicated by the thumb.

Question #164 Key: (C)PHYSICS
11. Electromagnetic Induction

An alternating current electrical transformer operates on the principle of:

CORE CONCEPT & DERIVATION

A transformer transfers electrical energy between two or more coupled coils through a time-varying magnetic flux.

Formula / Rule / Reaction:

$$E_s = -M \frac{dI_p}{dt} = -N_s \frac{d\Phi_B}{dt}$$

Solution:

- Alternating current in the primary winding produces a continuously changing magnetic flux in the ferromagnetic core.
- This changing flux links with the secondary coil, inducing an alternating electromotive force across its terminals by mutual induction.

Why other options are incorrect:

- **Option A:** Lenz's law gives the direction of induced EMF, but mutual induction is the operational mechanism.
- **Option B:** Coulomb's law governs static forces between charges.
- **Option D:** Ampere's law relates magnetic fields to steady currents, but it does not account for induced EMF.

Question #165 Key: (D)PHYSICS
11. Electromagnetic Induction

While ideal transformers are 100% efficient, well-designed commercial power transformers typically...

CORE CONCEPT & DERIVATION

Transformer efficiency is the ratio of output power to input power, reduced in practice by core and copper losses.

Formula / Rule / Reaction:

$$\eta = \frac{P_{\text{out}}}{P_{\text{in}}} \times 100\%$$

Solution:

- Because transformers are static machines with no moving parts, mechanical friction is absent.
- Energy losses are limited to hysteresis, eddy currents, and resistive heating (copper loss), allowing practical commercial transformers to reach efficiencies around 90% or higher.

Why other options are incorrect:

- **Option A:** 60% represents an inefficient machine with severe thermal losses.
- **Option B:** 70% is characteristic of small heat engines, well below transformer efficiency.
- **Option C:** 80% is lower than the typical efficiency of commercial transformers.

Question #166 Key: (B)PHYSICS
11. Electromagnetic Induction

Lenz's law of electromagnetic induction is a direct consequence of the law of conservation of:

CORE CONCEPT & DERIVATION

Induced currents flow in a direction such that their magnetic field opposes the change in flux that produced them.

Formula / Rule / Reaction:

$$\mathcal{E} = -N \frac{d\Phi_B}{dt} \quad (\text{Negative sign embodies Lenz's Law})$$

Solution:

- Mechanical work must be done against the opposing magnetic force created by the induced current.
- This mechanical work is converted into electrical energy in the circuit, satisfying the law of conservation of energy.

Why other options are incorrect:

- **Option A:** Conservation of electric charge is described by Kirchhoff's current law.
- **Option C:** Conservation of linear momentum applies to collision mechanics in isolated systems.
- **Option D:** Mass conservation is preserved in non-relativistic chemical processes, not specifically by Lenz's law.

Question #167 Key: (C)PHYSICS
13. Electronics

A circuit that converts only one half of an alternating current input waveform into direct curr...

CORE CONCEPT & DERIVATION

Rectification converts bidirectional alternating current (AC) into unidirectional direct current (DC).

Formula / Rule / Reaction:

$$V_{dc} = \frac{V_m}{\pi} \approx 0.318V_m \quad (\text{Half-Wave})$$

Solution:

- A half-wave rectifier uses a single diode that conducts only during positive half-cycles and blocks negative half-cycles.
- This produces a pulsating direct current output during alternate half-cycles.

Why other options are incorrect:

- **Option A:** A full-wave rectifier inverts both half-cycles into the same output polarity.
- **Option B:** An amplifier increases the amplitude of a signal without converting AC to DC.
- **Option D:** An inverter converts direct current into alternating current.

Question #168 Key: (D)PHYSICS
13. Electronics

The maximum theoretical efficiency of a full-wave rectifier is approximately how many times tha...

CORE CONCEPT & DERIVATION

Rectifier efficiency measures the ratio of DC output power to AC input power.

Formula / Rule / Reaction:

$$\eta_{\text{half-wave}} = \frac{0.406R_L}{r_f + R_L} \approx 40.6\%, \quad \eta_{\text{full-wave}} = \frac{0.812R_L}{r_f + R_L} \approx 81.2\%$$

Solution:

- Calculate the ratio:

$$\frac{\eta_{\text{full-wave}}}{\eta_{\text{half-wave}}} = \frac{81.2\%}{40.6\%} = 2$$

- Thus, a full-wave rectifier has double the theoretical efficiency of a half-wave rectifier.

Why other options are incorrect:

- **Option A:** Four times would require an efficiency of over 160%, which violates energy conservation.
- **Option B:** Efficiencies are not equal because full-wave circuits utilize both half-cycles.
- **Option C:** Sixteen times is mathematically incorrect.

Question #169 Key: (A)PHYSICS
13. Electronics

Which electronic semiconductor component conducts current primarily in one direction and is used...

CORE CONCEPT & DERIVATION

A p-n junction diode acts as a one-way valve for electric current by conducting when forward-biased and blocking when reverse-biased.

Formula / Rule / Reaction:

$$I = I_0 \left(e^{qV/\eta k_B T} - 1 \right)$$

Solution:

- Under forward bias, the depletion layer narrows, permitting current flow.
- Under reverse bias, the barrier height increases, reducing current to a negligible leakage value.
- This unidirectional conduction allows the diode to rectify AC into pulsating DC.

Why other options are incorrect:

- **Option B:** Transistors are three-terminal devices used primarily for amplification and switching.
- **Option C:** Transformers alter AC voltage levels; they do not rectify AC into DC.
- **Option D:** Inductors oppose changes in current, functioning as filters rather than rectifiers.

Question #170 Key: (C)PHYSICS
14. Dawn of Modern Physics

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

CORE CONCEPT & DERIVATION

Photochemical reactions require photon energies that exceed the activation threshold of silver halide emulsion crystals.

Formula / Rule / Reaction:

$$E = hf = \frac{hc}{\lambda} \quad (\lambda_{\text{red}} \approx 700 \text{ nm}, f_{\text{red}} \approx 4.3 \times 10^{14} \text{ Hz})$$

Solution:

- Red light has the longest wavelength and lowest frequency in the visible spectrum.
- Because their quantum energy ($E = hf$) is low, red photons do not trigger premature chemical reduction of photographic silver halide emulsions.

Why other options are incorrect:

- **Option A:** Red light has the lowest frequency and longest wavelength among visible colors.
- **Option B:** Lower frequency corresponds to longer wavelength, not shorter.
- **Option D:** Higher frequency would mean higher photon energy, which would expose the film.

Question #171 Key: (B)PHYSICS
14. Dawn of Modern Physics*Which photons in the visible spectrum carry the greatest quantum energy?***CORE CONCEPT & DERIVATION**

The energy of an electromagnetic photon is directly proportional to its frequency and inversely proportional to its wavelength.

Formula / Rule / Reaction:

$$E = hf = \frac{hc}{\lambda} \quad (\lambda_{\text{violet}} \approx 380 - 400 \text{ nm})$$

Solution:

- Violet light has the shortest wavelength and highest frequency in the visible spectrum.
- Consequently, violet photons carry the largest quantum energy (approximately 3.1 eV), compared to blue (2.7 eV), green (2.3 eV), and red (1.8 eV).

Why other options are incorrect:

- **Option A:** Blue light has a longer wavelength (around 450 to 480 nm) than violet, so its photon energy is lower.
- **Option C:** Red photons have the lowest energy in the visible spectrum (around 1.8 eV).
- **Option D:** Green photons carry intermediate energy (around 2.3 eV).

Question #172 Key: (C)PHYSICS
15. Atomic Spectra*In the hydrogen atomic emission spectrum, which spectral line series lies entirely in the ultra...***CORE CONCEPT & DERIVATION**

Spectral series arise from electron transitions from higher energy levels down to a common lower principal quantum state.

Formula / Rule / Reaction:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \quad (\text{Lyman: } n_1 = 1, n_2 = 2, 3, 4, \dots)$$

Solution:

- The Lyman series corresponds to transitions ending at the ground state ($n_1 = 1$).
- Because transitions to $n = 1$ involve the largest energy gaps, their emissions have short wavelengths (91 to 122 nm) that fall entirely in the ultraviolet region.

Why other options are incorrect:

- **Option A:** The Balmer series (transitions to $n_1 = 2$) falls primarily in the visible spectrum.
- **Option B:** The Paschen series (transitions to $n_1 = 3$) lies in the near-infrared region.
- **Option D:** The Brackett series (transitions to $n_1 = 4$) lies in the infrared region.

Question #173 Key: (D)PHYSICS
15. Atomic Spectra

Which of the following characteristic X-ray transitions emits a photon with the longest wavelength...

CORE CONCEPT & DERIVATION

The wavelength of an emitted X-ray photon is inversely proportional to the energy difference between the initial and final atomic states.

Formula / Rule / Reaction:

$$\lambda = \frac{hc}{\Delta E} \Rightarrow \text{Smallest } \Delta E \Rightarrow \text{Longest } \lambda$$

Solution:

- Transitions to the K -shell ($n = 1$) involve large energy differences, producing short-wavelength hard X-rays.
- Transitions within higher shells (such as the M -series where $n_1 = 3$) involve much smaller energy differences.
- Because ΔE is smallest for the M series, it produces photons with the longest wavelengths.

Why other options are incorrect:

- **Option A:** K_α transitions ($L \rightarrow K$) release substantial energy, yielding short wavelengths.
- **Option B:** K_β transitions ($M \rightarrow K$) involve a larger energy drop than K_α , giving a shorter wavelength.
- **Option C:** K_γ transitions involve an even larger energy gap, yielding very short wavelengths.

Question #174 Key: (B)PHYSICS
16. Nuclear Physics

The radioactive half-life of Iodine-131 ([Formula]), used clinically in thyroid radiometry, is...

CORE CONCEPT & DERIVATION

Radioactive half-life is the time required for half of the unstable nuclei in a radionuclide sample to undergo decay.

Formula / Rule / Reaction:

$$N(t) = N_0 \left(\frac{1}{2}\right)^{t/T_{1/2}} \quad (T_{1/2} \text{ for } ^{131}\text{I} \approx 8.02 \text{ days})$$

Solution:

- Iodine-131 decays via beta and gamma emission with a half-life of approximately 8 days (8.02 days).
- This relatively short half-life makes it suitable for diagnostic and therapeutic treatment of thyroid conditions.

Why other options are incorrect:

- **Option A:** 10 days is an overestimation of the half-life of ^{131}I .
- **Option C:** 45 days is close to the half-life of Iron-59 (44.5 days).
- **Option D:** 60 days is approximately the half-life of Iodine-125 (59.4 days).

Question #175 Key: (B)PHYSICS
16. Nuclear Physics

The half-life of Carbon-14 is 5,730 years. What fraction of the original radioactive Carbon-14 ...

CORE CONCEPT & DERIVATION

Radioactive decay follows an exponential decay law governed by the number of elapsed half-lives.

Formula / Rule / Reaction:

$$n = \frac{t}{T_{1/2}}, \quad \text{Fraction Remaining} = \left(\frac{1}{2}\right)^n$$

Solution:

- Calculate the number of elapsed half-lives n :
- $$n = \frac{22,920 \text{ years}}{5,730 \text{ years}} = 4 \text{ half-lives}$$
- Determine the remaining fraction:

$$\text{Fraction} = \left(\frac{1}{2}\right)^4 = \frac{1}{16}$$

Why other options are incorrect:

- Option A:** $\frac{1}{32}$ corresponds to 5 half-lives (28,650 years).
- Option C:** $\frac{1}{64}$ corresponds to 6 half-lives (34,380 years).
- Option D:** $\frac{1}{8}$ corresponds to 3 half-lives (17,190 years).

Question #176 Key: (A)PHYSICS
16. Nuclear Physics

Radiation-induced injuries such as skin burns, epilation (hair loss), and a drop in white blood...

CORE CONCEPT & DERIVATION

Biological radiation effects are categorized into somatic effects (appearing in the exposed person) and genetic effects (affecting future generations).

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Somatic effects result from radiation damage to non-germline body tissues.
- Early somatic effects include skin burns (erythema), hair loss, bone marrow suppression, and acute radiation sickness occurring directly in the exposed individual.

Why other options are incorrect:

- Option B:** Genetic effects result from DNA damage to germ cells (sperm or ova) that is passed on to offspring.
- Option C:** Metabolic effects is not a standard formal radiobiological classification.
- Option D:** Teratogenic effects specifically refer to developmental malformations induced in an exposed embryo or fetus in utero.

Question #177 Key: (D)ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

The word RITUAL most nearly means:

CORE CONCEPT & DERIVATION

Vocabulary analysis requires identifying the definition that best matches traditional usage.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- A ritual is an established, solemn ceremony or customary series of actions performed according to a prescribed order.
- Among the options, 'custom' is the closest synonym.

Why other options are incorrect:

- Option A:** Original refers to the source or beginning of something, not a repeated ceremony.
- Option B:** Religion is a broader belief system that may include rituals, but the words are not synonymous.
- Option C:** Routine refers to regular, mundane daily habits, lacking the solemn or traditional character of a ritual.

Question #178 **Key: (B)**ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

Choose the option with the correct spelling:

CORE CONCEPT & DERIVATION

Orthography evaluation requires identifying the correct historical spelling derived from French.

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

- The word is spelled **Renaissance** (derived from the French *renaître*, meaning 'rebirth').
- It contains 'Re-' followed by '-naissance' with double 's'.

Why other options are incorrect:

- **Option A:** 'Renessance' incorrectly uses 'e' instead of 'ai'.
- **Option C:** 'Renaissance' misses the double 's'.
- **Option D:** 'Reniasance' transposes the 'a' and 'i'.

Question #179 **Key: (C)**ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

Choose the option with the correct spelling:

CORE CONCEPT & DERIVATION

Standard English orthography rules govern Latin-derived adjectives ending in '-ent'.

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

- The correct spelling is **Expedient** (meaning convenient, practical, or suitable for a purpose).
- It derives from the Latin *expedire*.

Why other options are incorrect:

- **Option A:** 'Expident' omits the required 'e'.
- **Option B:** 'Expedeint' transposes the 'e' and 'i'.
- **Option D:** 'Expediant' incorrectly uses the suffix '-ant' instead of '-ent'.

Question #180 **Key: (C)**ENGLISH
06. Punctuation, Capitalization & Reading Comprehension

Choose the option with the correct spelling:

CORE CONCEPT & DERIVATION

Standard English noun formation from the root 'deficit' follows conventional prefix and suffix patterns.

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

- The correct spelling is **Deficiency** (meaning a lack or shortage).
- It contains a single 'f' and uses 'i' before 'c'.

Why other options are incorrect:

- **Option A:** 'Deficiency' incorrectly doubles the consonant 'f'.
- **Option B:** 'Daficiency' incorrectly substitutes 'a' in the first syllable.
- **Option D:** 'Defeciency' incorrectly uses 'e' in the second syllable.

Question #181 **Key: (B)**ENGLISH
03. Parts of Speech, Prepositions & Modifiers

Fill in the blank with the appropriate preposition: Finally, the accused was found guilty _____.

CORE CONCEPT & DERIVATION

In English grammar, specific adjectives take fixed prepositions to link to their objects.

Formula / Rule / Reaction:Adjective Phrase: **Guilty + of + [Offense / Charge]****Solution:**

- The adjective 'guilty' takes the dependent preposition 'of' when designating a crime or offense.
- Therefore, the correct phrasing is 'guilty of his crime'.

Why other options are incorrect:

- **Option A:** 'Guilty from' is ungrammatical.
- **Option C:** 'Guilty for' is an incorrect prepositional pairing.
- **Option D:** 'Guilty to' is ungrammatical in this context.

Question #182 **Key: (B)**ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

Select the word that best completes the sentence: *The hundreds of years old palace could not wi...*

CORE CONCEPT & DERIVATION

Contextual vocabulary selection requires matching the word to the physical damage caused by natural events.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- 'Havoc' means widespread destruction, ruin, or devastation, fitting the physical damage caused by severe weather.
- The phrase 'withstand the havoc of heavy rain' provides the most appropriate meaning.

Why other options are incorrect:

- **Option A:** 'Aftermath' refers to the subsequent consequences or period following an event; a structure resists the destructive force itself, not the aftermath.
- **Option C:** 'Annoyance' refers to a minor psychological irritation, not physical destruction.
- **Option D:** 'Massacre' refers specifically to the brutal slaughter of living beings.

Question #184 **Key: (C)**ENGLISH
05. Active-Passive Voice, Reported Speech & Syntax

Classify the following sentence according to its grammatical mood and function: *How cold the ni...*

CORE CONCEPT & DERIVATION

Sentences are categorized by purpose into declarative, interrogative, imperative, and exclamatory forms.

Formula / Rule / Reaction:

Exclamatory Structure: **How** + Adjective + Subject + Verb+!

Solution:

- The sentence begins with 'How' followed by an adjective, subject, and verb, and ends with an exclamation point.
- Because it expresses strong emotion and emphasis, it is an exclamatory sentence.

Why other options are incorrect:

- **Option A:** Interrogative sentences ask questions, typically feature inverted auxiliary verbs, and end with question marks.
- **Option B:** Declarative sentences make straightforward statements and end with periods.
- **Option D:** Imperative sentences issue direct commands, instructions, or requests.

Question #183 **Key: (B)**ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

Select the most appropriate verb to fill in the blank: *He began to _____ the heap of corns very...*

CORE CONCEPT & DERIVATION

Verbs of visual examination are distinguished by their degree of scrutiny and physical context.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- 'Inspect' means to look at something closely and critically to check its condition.
- It is the most natural verb for closely examining a physical collection of objects like a heap of grain.

Why other options are incorrect:

- **Option A:** 'Assess' generally implies estimating value, tax, or performance rather than close physical visual examination.
- **Option C:** 'Analyze' refers to breaking down complex data or chemical compounds into components.
- **Option D:** 'Evaluate' means to form a qualitative judgment regarding overall merit or worth.

Question #185 **Key: (D)**ENGLISH
06. Punctuation, Capitalization & Reading Comprehension

Identify the version of the sentence that contains correct punctuation, spelling, and clause st...

CORE CONCEPT & DERIVATION

Independent clauses must be joined using a semicolon or a coordinating conjunction with a comma to prevent comma splices.

Formula / Rule / Reaction:

Independent Clause 1 ; Independent Clause 2

Solution:

- Option D correctly separates the two independent clauses ('Tennis gives you plenty of exercise' and 'it develops...') with a semicolon.
- All words are spelled correctly ('plenty', 'quickness', 'brain', 'into'), and commas set off the appositive phrase ('your thinking power').

Why other options are incorrect:

- **Option A:** Creates a comma splice between the first two clauses and misidentifies 'intoo'.
- **Option B:** Contains misspellings ('plenti', 'off') and garbled clause structure.
- **Option C:** Contains misspellings ('limbupon', 'brane') and fragmented syntax.

Question #186 **Key: (C)**ENGLISH
05. Active-Passive Voice, Reported Speech & Syntax

Complete the cleft sentence with the grammatically correct verb form: It _____ good players who...

CORE CONCEPT & DERIVATION

In an 'it'-cleft sentence, the dummy pronoun 'it' serves as the grammatical subject and takes a singular verb.

Formula / Rule / Reaction:

It + singular verb (is/was) + Focus Nominal + Relative Clause

Solution:

- The preparatory subject 'it' is singular and requires a singular present-tense verb ('is').
- Even though the focused complement ('good players') is plural, the cleft copula agrees with 'it': 'It is good players who...'

Why other options are incorrect:

- **Option A:** 'Was' is singular but past tense; the relative clause uses the present tense 'bring'.
- **Option B:** 'Were' is a plural past-tense verb that violates agreement with 'it'.
- **Option D:** 'Are' incorrectly attempts to agree with the plural complement rather than the dummy subject 'it'.

Question #187 **Key: (C)**ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Choose the grammatically correct modal auxiliary verb to fill in the blank: I don't think I ____.

CORE CONCEPT & DERIVATION

In formal British English, the modal auxiliary 'shall' is used with first-person subjects (I, we) to express future possibility.

Formula / Rule / Reaction:

I/We + shall + be able to + [verb]

Solution:

- 'Shall' combined with 'be able to' indicates future ability or contingency.
- Using 'can' alongside 'be able to' is redundant, making 'shall' the correct choice.

Why other options are incorrect:

- **Option A:** 'Can be able to' creates grammatical redundancy because both denote ability.
- **Option B:** 'Should' introduces an unintended sense of obligation.
- **Option D:** 'Must' denotes strong compulsion, which does not fit the tentative context.

Question #188 **Key: (D)**ENGLISH
06. Punctuation, Capitalization & Reading Comprehension

Fill in the blank with the appropriate verb form: Ethics _____ important for a peaceful and lov...

CORE CONCEPT & DERIVATION

Nouns ending in '-ics' that refer to a field of study, philosophy, or academic discipline take a singular verb.

Formula / Rule / Reaction:

Subject (Discipline of Ethics) ⇒ Singular Verb (is)

Solution:

- When 'Ethics' refers to moral philosophy or the general concept of morality, it is treated as a singular mass noun taking the singular verb 'is'.
- **Note:** If used to describe specific individual moral practices or codes of conduct, it can take a plural verb; however, here it denotes the broad concept, so 'is' is standard.

Why other options are incorrect:

- **Option A:** 'Have' is a plural transitive auxiliary verb that does not fit the predicate adjective 'important'.
- **Option B:** 'Has' is a singular transitive verb that requires a noun phrase or participle.
- **Option C:** 'Are' treats the noun as plural, which is less appropriate when referring to the collective concept of ethics.

Question #189 **Key: (C)**ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Select the correct verb phrase to complete the sentence: *Engineers _____ working on a new proje...*

CORE CONCEPT & DERIVATION

An action that began in the past and continues into the present over a specified duration requires the present perfect continuous tense.

Formula / Rule / Reaction:

Plural Subject + **have been** + V-ing + **for** + [Time Duration]

Solution:

- The time phrase 'for the last three days' specifies an ongoing duration, requiring the present perfect continuous tense.
- Because the subject 'Engineers' is plural, it takes the plural auxiliary 'have been working'.

Why other options are incorrect:

- Option A:** 'Are' is present continuous and cannot be paired with a duration phrase introduced by 'for'.
- Option B:** 'Has been' is singular, violating subject-verb agreement with the plural noun 'Engineers'.
- Option D:** 'Ought to be' expresses obligation, not an observed ongoing action.

Question #190 **Key: (B)**ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

The word **CREDENTIALS** most nearly refers to:

CORE CONCEPT & DERIVATION

Credentials refers to evidence of competence, authority, or professional status.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Credentials are documents, certificates, degrees, or references attesting to a person's identity, qualifications, or professional competence.
- Therefore, 'qualifications' is the closest synonym.

Why other options are incorrect:

- Option A:** Trust is an interpersonal feeling, not documentation of competence.
- Option C:** Financial credits refer to monetary funds or credit lines.
- Option D:** Personal beliefs are individual convictions, not professional qualifications.

Question #191 **Key: (A)**ENGLISH
06. Punctuation, Capitalization & Reading Comprehension

Choose the option with correct punctuation, spelling, and conjunction usage:

CORE CONCEPT & DERIVATION

When coordinating three short, related independent clauses in a series, separate them with commas and place a coordinating conjunction before the final clause.

Formula / Rule / Reaction:

Clause 1, Clause 2, **and** Clause 3.

Solution:

- Option A uses commas after each clause in the three-part series, followed by the coordinating conjunction 'and'.
- All words are spelled correctly ('blew', 'lightning').

Why other options are incorrect:

- Option B:** Contains the homophone misspelling 'blue' for 'blew' and lacks a comma after the first clause.
- Option C:** Lacks commas between clauses and misspells 'lightening' for 'lightning'.
- Option D:** Misspells 'lightening' and uses a semicolon before the coordinating conjunction 'and'.

Question #192 **Key: (B)**ENGLISH
06. Punctuation, Capitalization & Reading Comprehension

Identify the option that correctly renders the traditional English proverb:

CORE CONCEPT & DERIVATION

Proverbs rely on fixed, historically established idiomatic phrasing.

Formula / Rule / Reaction:

Standard Proverb: **Time and tide wait for no man.**

Solution:

- The traditional proverb 'Time and tide wait for no man' emphasizes that time continues to pass regardless of individual actions.
- 'Time and tide' is treated as a compound subject taking the plural base verb 'wait'.

Why other options are incorrect:

- Option A:** Omits the conjunction 'and' and incorrectly substitutes the plural 'men'.
- Option C:** Adds unnecessary definite articles and misspells 'weight' for 'wait'.
- Option D:** Contains garbled syntax and misspellings ('know' for 'no').

Question #193 Key: (B)ENGLISH
02. Idioms, Phrasal Verbs & Literary Figures

Select the appropriate phrasal verb to complete the sentence: Negotiations between the two side...

CORE CONCEPT & DERIVATION

Phrasal verbs combine verbs with prepositions or particles to convey specific idiomatic meanings.

Formula / Rule / Reaction:

Break down $\Rightarrow$ To collapse, fail, or cease to function

Solution:

- 'Break down' is the standard phrasal verb used when talks, discussions, or negotiations fail due to disagreement.
- Thus, 'negotiations have broken down' is the correct idiom.

Why other options are incorrect:

- **Option A:** 'Break off' means to abruptly discontinue or terminate a relationship, which is less idiomatic for the collapse of formal talks.
- **Option C:** 'Break up' refers to the disbanding of an assembly, school term, or romantic relationship.
- **Option D:** 'Break in' means to enter forcibly or train someone into a new role.

Question #194 Key: (A)ENGLISH
05. Active-Passive Voice, Reported Speech & Syntax

Choose the sentence that is grammatically correct:

CORE CONCEPT & DERIVATION

Grammatical correctness requires proper passive construction and strict subject-verb agreement.

Formula / Rule / Reaction:

Passive: Subject (Your voice) + **was** + V₃(recognized) + **by** + Agent(me)

Solution:

- Option A correctly uses the singular auxiliary 'was' with the singular subject 'voice', along with the proper past participle 'recognized'.

Why other options are incorrect:

- **Option B:** Uses the singular auxiliary 'has' with the plural subject 'boats' (should be 'have been lost').
- **Option C:** Treats the collective noun 'committee' as plural without justification (should be 'was appointed' when acting as a single unit).
- **Option D:** Uses the plural verb 'were' with the singular collective noun 'crowd' describing size (should be 'was very big').

Question #195 Key: (B)LOGICAL REASONING
04. Argument Evaluation & Ethics

Read the passage and assess the statements below based solely on the provided text: 'The Early ...

CORE CONCEPT & DERIVATION

Reading comprehension conclusions must be directly supported by textual evidence without introducing external assumptions.

Formula / Rule / Reaction:

Logical deduction from given premises.

Solution:

- Statement I is stated directly in the first sentence ('witnessed the spread of Islam in the region...').
- Statement II is supported by the second sentence ('converting a majority of the regional Buddhist and Hindu population...').
- Statement III makes an unverified claim that Sufis were the 'sole cause' of Pakistan's modern status, which is not stated in the passage.

Why other options are incorrect:

- **Option A:** Overlooks Statement II, which is also supported by the text.
- **Option C:** Includes Statement III, which is an unsupported overstatement.
- **Option D:** Erroneously includes Statement III while omitting Statement II.

Question #196 Key: (C)

LOGICAL REASONING

14. Direction, Distance & Spatial/Visual Patterns

Select the shape configuration that logically comes next in the cyclical rotating sequence: $\odot \bullet \dots$

CORE CONCEPT & DERIVATION

Symbolic pattern logic tracks the permutation and rotational rules governing the position of elements between successive terms.

Formula / Rule / Reaction:

Term 1: $[A, B, C, D] \rightarrow$ Term 2: $[B, D, C, A] \rightarrow \dots \rightarrow$ Term 5: $[A, B, D, C]$

Solution:

- Track the leading symbol in each box: Term 1 starts with $\odot$, Term 2 with $\bullet$, Term 3 with $\bullet$, and Term 4 with $\bullet$.
- Following this four-element cycle, Term 5 must return to starting with $\odot$.
- Comparing the relative positions in Term 4 ($\bullet \odot \bullet \bullet$), rotating the leading element $\bullet$ to the end yields $\odot \bullet \bullet \bullet$, which matches Option C.

Why other options are incorrect:

- Option A:** Starts with $\bullet$, which was the leading symbol of Term 3.
- Option B:** Starts with $\bullet$, which was the leading symbol of Term 2.
- Option D:** Repeats Term 1 directly without applying the permutation observed in the middle elements.

Question #197 Key: (B)

LOGICAL REASONING

11. Set Theory, Integer Bounds & Arithmetic

Three whole numbers $[Formula]$, $[Formula]$, and $[Formula]$ are all greater than 11 and less than...

CORE CONCEPT & DERIVATION

Deductive number theory requires identifying prime numbers and multiples within a defined bounded set.

Formula / Rule / Reaction:

Domain: $S = \{12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23\}$

Solution:

- Primes in S are $\{13, 17, 19, 23\}$. The smallest prime is $X = 13$.
- Multiples of 3 in S are $\{12, 15, 18, 21\}$. The largest is $Y = 21$ (24 is excluded because numbers must be less than 24).
- Multiples of 11 in S include only 22 (11 is excluded because numbers must be greater than 11). Thus, $Z = 22$.
- Therefore, $X = 13$, $Y = 21$, and $Z = 22$.

Why other options are incorrect:

- Option A:** Violates the upper bound ($Y = 24$ is not less than 24) and the lower bound ($Z = 11$ is not greater than 11).
- Option C:** Violates the lower bound for X and Z (11 is not greater than 11).
- Option D:** Incorrectly sets $X = 11$ and $Y = 24$, violating both range boundaries.

Question #198 Key: (A)LOGICAL REASONING
02. Cause and Effect Analysis

Read the two statements and choose the correct option describing their causal relationship: Sta...

CORE CONCEPT & DERIVATION

Cause-and-effect reasoning evaluates whether one event is the direct catalyst that precipitates another event.

Formula / Rule / Reaction:

Tax Increase (Fiscal Cause) $\Rightarrow$ Business Closures (Economic Effect)

Solution:

- Increasing taxes increases operating overhead and reduces profit margins, particularly for small enterprises with limited cash reserves.
- This added cost forces marginal small businesses to shut down, making Statement I the direct cause and Statement II its logical effect.

Why other options are incorrect:

- Option B:** Small business closures do not cause the government to raise taxes across all businesses.
- Option C:** The two events are directly linked, not independent causes.
- Option D:** Statement II is a direct consequence of Statement I, not an effect of an unrelated cause.

Question #199 Key: (A)LOGICAL REASONING
03. Courses of Action & Decision-Making

Read the statement and determine which suggested course of action logically follows: Statement:...

CORE CONCEPT & DERIVATION

A valid course of action must be practical, proportionate, and directly resolve the stated issue.

Formula / Rule / Reaction:

Evaluation of practical problem-solving.

Solution:

- Course I is practical: ceasing use conserves remaining battery power until a charger can be connected.
- Course II is impractical and disproportionate: rechargeable laptop batteries are designed to be recharged, not replaced with a new purchase whenever depleted.
- Therefore, only Course I logically follows.

Why other options are incorrect:

- Option B:** Buying a new battery whenever the charge is low is wasteful and impractical.
- Option C:** Erroneously includes Course II.
- Option D:** Course I is a sensible, logical step to prevent power loss.

Question #200 **Key: (D)**LOGICAL REASONING
05. Categorical Syllogisms & Overlapping Sets

Given the following categorical premises: • All hammers are tools. • Some tools are useless thi...

CORE CONCEPT & DERIVATION

Categorical syllogisms combine class inclusions to establish valid deductions without illicit distribution.

Formula / Rule / Reaction:

Some Tools $\subset$ Useless Things and Useless Things $\subseteq$ Trash

Solution:

- Because 'some tools are useless things' and 'all useless things are trash', the subset of tools that are useless must also be trash.
- This makes Conclusion II ('Some tools are trash') necessarily true.
- Conclusion I ('Some hammers are trash') is invalid because hammers may belong entirely to the non-useless subset of tools.
- Conclusion III ('All useless things are tools') is an invalid conversion of the premise 'some tools are useless things'.

Why other options are incorrect:

- **Option A:** Conclusions I and III are logically invalid deductions.
- **Option B:** Conclusion I cannot be definitively deduced from the premises.
- **Option C:** Conclusion III commits the fallacy of illicit conversion.