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NUMS RAWALPINDI

NUMS 2024 Official Solved Paper

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

🛡️ Official Admitting Board: National University of Medical Sciences 🎯 Archive Code: BEAMBE-FLP-NUMS-2024 ⌚ Duration: 150 Minutes (2h 30m)

150 TOTAL QUESTIONS	150m OFFICIAL DURATION	+1 / 0.00 ZERO NEGATIVE MARKING	150 MAXIMUM MARKS
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📄 EXAMINATION BLUEPRINT & SUBJECT WEIGHTAGE

Biology 55 MCQs 36.7% weight	Chemistry 40 MCQs 26.7% weight	Physics 40 MCQs 26.7% weight	English 15 MCQs 10.0% weight
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BIO SECTION: BIOLOGY

Questions 1 to 55 (55 MCQs)

Q1. BIO

Which function cannot be attributed to plasma membrane lipids?

- (A) Recognition of cells having non-self surface markers
- (B) Maintaining cell membrane flexibility and fluidity
- (C) Catalytic control of metabolic reactions across the cell membrane
- (D) Participating in intracellular signaling responses

Q2. BIO

Follow the correct secretory route of pepsinogen produced by gastric chief cells:

- (A) RER → Transitional ER → Golgi complex → Secretory vesicles
- (B) SER → RER → Golgi complex → Secretory vesicles
- (C) SER → Mitochondria → Golgi complex → Secretory vesicles
- (D) Golgi complex → RER → SER → Secretory vesicles

Q3. BIO

The low chemical reactivity of sucrose relative to monosaccharides is due to its:

- (A) High solubility in aqueous medium
- (B) Polar characteristics
- (C) Unavailability of free anomeric functional groups
- (D) Presence of a stable peptide linkage

Q4. BIO

Sucrose is used as a transport carbohydrate in vascular plants instead of glucose because:

- (A) It is an insoluble disaccharide
- (B) It is a non-reducing sugar
- (C) It breaks down spontaneously into starch during transit
- (D) It avoids altering the osmotic potential of sieve tube sap

Q5. BIO

Coronavirus is an enveloped virus. Alcohol-based hand sanitizers and surface cleaners were widely recommended during the COVID-19 pandemic. Which property of the coronavirus makes these chemical products effective?

- (A) pH sensitivity and lipid membrane vulnerability
- (B) Extreme thermophilic stability
- (C) Single-stranded RNA genome resistance
- (D) Intracellular hypotonicity

Q6. BIO

Proteins exhibiting a tertiary structure are primarily responsible for:

- (A) Carrying messages from endocrine glands to target tissues
- (B) Forming the insoluble epithelial barrier of the skin
- (C) Providing tensile strength to the extracellular matrix of bone
- (D) Serving as purely passive structural struts in hair fibers

Q7. BIO

Chemical rebonding is used to straighten curly hair. Which chemical bond is targeted and reformed by oxidizing agents during this process?

- (A) Peptide bond
- (B) Ionic salt bridge
- (C) Disulphide bridge
- (D) Phosphodiester bond

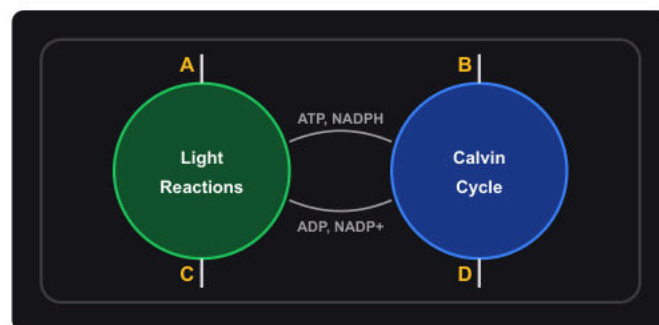
Q8. BIO

Ions of heavy metals are harmful to living organisms primarily because of their ability to:

- (A) Enzymatically cleave chromosomal DNA backbones
- (B) Accelerate cellular fat metabolism uncontrollably
- (C) Hydrolyze starch glycosidic bonds non-specifically
- (D) Destabilize and denature functional proteins

Q9. BIO

Choose the option showing the correct labeling of inputs and outputs in the generalized photosynthetic diagram below:



- (A) A: CO₂, B: O₂, C: H₂O, D: Sugar
- (B) A: H₂O, B: Sugar, C: CO₂, D: O₂
- (C) A: H₂O, B: CO₂, C: O₂, D: Sugar
- (D) A: O₂, B: CO₂, C: H₂O, D: Sugar

Q10. BIO

Which mechanism would be directly compromised in the absence of the cytochrome complex during the light-dependent reactions of photosynthesis?

- (A) Initial photolysis of water in the PS II oxygen-evolving complex
- (B) Photoexcitation of P680 reaction center chlorophyll
- (C) Direct light absorption by accessory carotenoids
- (D) Establishment of the proton gradient across the thylakoid membrane

Q11. BIO

During glycolysis, an enzymatic isomerization reaction takes place in the interconversion of:

- (A) Dihydroxyacetone phosphate and glyceraldehyde-3-phosphate
- (B) Glyceraldehyde-3-phosphate and fructose-6-phosphate
- (C) Phosphoenolpyruvate and pyruvate
- (D) Fructose-6-phosphate and 3-phosphoglycerate

Q12. BIOThe presence of PEP carboxylase in C₄ plants enables them to avoid photorespiration because:

- (A) The enzyme exists in exceptionally high cellular concentration
- (B) Rubisco is completely absent throughout the entire plant
- (C) PEP carboxylase acts strictly as a carboxylase with no affinity for oxygen
- (D) It consumes oxygen to synthesize additional ATP

Q13. BIO

Fats and proteins can both be used as respiratory fuels. Which molecule serves as the common intermediate through which their catabolism converges into the Krebs cycle?

- (A) Acetyl-CoA
- (B) Pyruvate
- (C) Glyceraldehyde-3-phosphate
- (D) Lactate

Q14. BIO

Which of the following viruses possesses a double-stranded DNA (dsDNA) genome?

- (A) Rubella virus
- (B) Influenza virus
- (C) Human immunodeficiency virus
- (D) Smallpox virus

Q15. BIO

An enzyme is capable of acting on a wide range of structurally related substrates. Which of the following is a characteristic property of this enzyme?

- (A) Rigid lock-and-key active site
- (B) Flexible active site conforming to induced-fit mechanisms
- (C) Absence of any tertiary protein structure
- (D) Requirement for inorganic cofactors exclusively

Q16. BIO

All of the following characteristics enhance the survival of encapsulated pathogenic bacteria EXCEPT:

- (A) High virulence and protection from phagocytosis
- (B) Resistance to environmental desiccation
- (C) Adherence to host epithelial surfaces
- (D) Easy recognition and clearance by host macrophages

Q17. BIO

Probiotics in infant formula milk represent normal gut microflora. They benefit infants through all of the following actions EXCEPT:

- (A) Synthesizing B-complex vitamins and vitamin K
- (B) Engulfing and destroying pathogens via cellular phagocytosis
- (C) Competitively excluding pathogens from attaching to mucosal surfaces
- (D) Promoting local mucosal and humoral immunity

Q18. BIO

Activation of all of the following digestive enzymes requires a specific activator molecule EXCEPT:

- (A) Pepsinogen
- (B) Trypsinogen
- (C) Erepsin
- (D) Chymotrypsinogen

Q19. BIO

Weakened or ruptured papillary muscles in the right ventricle will cause abnormal backflow of blood directly into the:

- (A) Right atrium
- (B) Left atrium
- (C) Left ventricle
- (D) Pulmonary trunk

Q20. BIO

A patient who has undergone cholecystectomy experiences difficulty in digesting large fatty meals because:

- (A) The liver stops synthesizing bile salts completely
- (B) Bile is released continuously in a dilute, uncontrolled manner
- (C) Pancreatic lipase secretion is irreversibly halted
- (D) Bile pigments are absent from the small intestine

Q21. BIO

The peroxisomal enzyme catalase protects plant cells from the toxic accumulation of:

- (A) Free nitrogen gas
- (B) Excess glucose-6-phosphate
- (C) Hydrogen peroxide produced during photorespiratory glycolate oxidation
- (D) Excess cellulose in the primary wall

Q22. BIO

Which set of anatomical characteristics correctly describes veins?

- (A) Valves: Present; Wall: Thinner than corresponding arteries; Lumen: Relatively wide
- (B) Valves: Absent; Wall: Thick muscular media; Lumen: Narrow and rigid
- (C) Valves: Present; Wall: Single endothelial layer; Lumen: Narrower than capillaries
- (D) Valves: Absent; Wall: Elastic with two cellular layers; Lumen: Variable

Q23. BIO

Which physiological parameter would remain UNCOMPROMISED in a patient following complete disruption of the lymphatic system?

- (A) Interstitial fluid balance and tissue edema prevention
- (B) Oxygen-carrying capacity of circulating blood
- (C) Dietary long-chain lipid absorption via intestinal lacteals
- (D) Trafficking of antigen-presenting cells to regional lymph nodes

Q24. BIO

The presence of which components primarily distinguishes circulating whole blood from interstitial fluid?

- (A) Dissolved glucose and sodium ions
- (B) Free amino acids and chloride anions
- (C) Bicarbonate buffers and urea molecules
- (D) Red blood cells and high-molecular-weight plasma proteins

Q25. BIO

Mesophytic plants placed in highly saline soils face physiological drought because:

- (A) Water potential of the soil is higher (less negative) than root water potential
- (B) The root cell membrane becomes entirely impermeable to water
- (C) Water potential of root cells is higher (less negative) than soil water potential
- (D) Soil osmotic pressure drops to zero

Q26. BIO

During the COVID-19 pandemic, the administration of convalescent plasma from recovered patients to severe cases provided clinical benefit. Which specific plasma component provided this protection?

- (A) High titers of specific neutralizing antibodies
- (B) Pro-inflammatory interleukin-1 cytokines
- (C) Unactivated plasminogen zymogens
- (D) Active pancreatic enzymes

Q27. BIO

Which of the following scenarios represents an example of artificial active immunity?

- (A) A fetus receiving maternal IgG antibodies across the placenta
- (B) A patient receiving an intravenous injection of anti-tetanus hyperimmune serum
- (C) An infant receiving the MMR (Measles, Mumps, Rubella) vaccine
- (D) A child developing lifelong immunity after recovering from a natural chickenpox infection

Q28. BIO

Which specific subset of T lymphocytes is required for the activation, clonal expansion, and antibody class switching of B lymphocytes?

- (A) Helper T cells ($CD4^+$)
- (B) Cytotoxic T cells ($CD8^+$)
- (C) Suppressor (Regulatory) T cells
- (D) Natural killer T cells

Q29. BIO

What is the normal physiological fate of neurotransmitter molecules after transmitting an action potential across a chemical synapse?

- (A) Permanent binding to postsynaptic ligand-gated channels
- (B) Complete conversion into ATP within the postsynaptic soma
- (C) Passive accumulation in the synaptic cleft for ongoing baseline stimulation
- (D) Rapid degradation by synaptic enzymes or removal via presynaptic reuptake

Q30. BIO

Which immediate event occurs at the postsynaptic membrane when an excitatory neurotransmitter binds its receptor?

- (A) Voltage-gated calcium channels open to trigger exocytosis
- (B) Ligand-gated sodium channels open, causing localized depolarization
- (C) Sodium-potassium ATPase pumps permanently stop operating
- (D) Chloride channels open, driving the potential toward -90 mV

Q31. BIO

During the propagation of an action potential along a neuronal axon, hyperpolarization (the undershoot phase) would NOT occur if:

- (A) Voltage-gated sodium channels failed to inactivate
- (B) Voltage-gated potassium channels closed immediately upon reaching the resting potential
- (C) The sodium-potassium ATPase pump stopped consuming ATP
- (D) Extracellular calcium concentrations dropped to zero

Q32. BIO

Which of the following is a characteristic feature of an electrical synapse?

- (A) A wide synaptic cleft measuring 20 to 40 nm
- (B) Requirement for neurotransmitter synthesis and vesicle fusion
- (C) A significant synaptic transmission delay of 1 to 2 ms
- (D) Direct continuity of cytoplasm through gap junction channels

Q33. BIO

Which statement correctly characterizes the absolute refractory period of an excitable neuronal membrane?

- (A) A second action potential can be elicited by applying a suprathreshold stimulus
- (B) The membrane potential reverses to -150 mV
- (C) No second action potential can be initiated regardless of stimulus strength
- (D) Sodium activation and inactivation gates are both held wide open

Q34. BIO

During the complex motor activity of flight, birds must coordinate many skeletal muscles simultaneously to control balance and trajectory. Which region of their brain must be exceptionally well-developed?

- (A) Cerebellum
- (B) Cerebrum
- (C) Amygdala
- (D) Hypothalamus

Q35. BIO

Which part of the human brain is most actively used by a mathematician when working through an original theoretical equation?

- (A) Medulla oblongata
- (B) Cerebrum
- (C) Amygdala
- (D) Pons

Q36. BIO

A mammal stranded in an arid desert faces severe dehydration. Which internal condition directly triggers the hypothalamic synthesis and posterior pituitary release of antidiuretic hormone (ADH)?

- (A) Marked decrease in blood plasma osmolarity
- (B) Elevated osmotic pressure (hyperosmolality) of circulating blood
- (C) Severe elevation in systemic arterial blood pressure
- (D) Excessive intake of hypotonic fluids

Q37. BIO

Which endocrine disorder is diagnosed in an adult patient presenting with thick, dry, and coarse skin, periorbital puffiness, lethargy, cold intolerance, and an abnormally low basal metabolic rate?

- (A) Cretinism
- (B) Cushing syndrome
- (C) Myxedema
- (D) Addison disease

Q38. BIO

Which of the following clinical conditions is directly associated with hypoparathyroidism?

- (A) Recurrent renal calculi and bone resorption
- (B) Persistent severe hypercalcemia
- (C) Hyperphosphatemic hypocalcemia causing neuromuscular tetany
- (D) Generalized muscular flaccidity

Q39. BIO

Choose the MISMATCHED endocrine pair regarding reproductive physiology:

- (A) Graafian follicle : Progesterone secretion
- (B) Interstitial cell stimulating hormone (ICSH) : Leydig cells
- (C) Estrogen : Negative feedback inhibition of FSH
- (D) Luteinizing hormone (LH) : Induction of ovulation

Q40. BIO

Which of the following physiological processes is governed by a negative feedback mechanism?

- (A) Platelet plug aggregation during primary hemostasis
- (B) Uterine myometrial contractions during parturition
- (C) Oxytocin-mediated milk ejection reflex during suckling
- (D) Regulation and maintenance of core body temperature

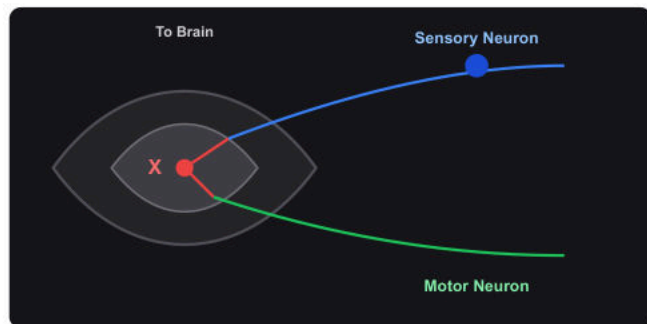
Q41. BIO

Most carbon dioxide is transported through the bloodstream as bicarbonate ions. Which of the following events does NOT occur during gaseous exchange at the systemic tissue level?

- (A) Binding of hydrogen ions by deoxyhemoglobin to form reduced hemoglobin (HHb)
- (B) Combination of bicarbonate with plasma sodium to form sodium bicarbonate
- (C) Reversible formation of oxyhemoglobin from deoxyhemoglobin
- (D) Chloride shift across the red blood cell membrane

Q42. BIO

The diagram below illustrates a spinal reflex arc with a neural component labeled X:



All of the following characteristics apply to the labeled interneuron X EXCEPT:

- (A) It projects ascending collaterals to transmit sensory signals to the brain
- (B) It transmits retrograde efferent feedback directly to peripheral sensory receptors
- (C) It forms chemical synapses with the terminal axon of a primary afferent sensory neuron
- (D) It is anatomically confined within the grey matter of the central nervous system

Q43. BIO

Which of the following functions is directly mediated by integral plasma membrane proteins?

- (A) Imposing an absolute physical barrier to the diffusion of non-polar gases
- (B) Preventing liquid crystal phase separation during extreme cold
- (C) Facilitated transport of inorganic ions down or against electrochemical gradients
- (D) Serving as the primary solvent matrix that determines bilayer fluidity

Q44. BIO

When grasped by a predator, a lizard can deliberately sever its own tail to escape. This physiological defense mechanism is known as:

- (A) Autophagy
- (B) Autotomy
- (C) Phagocytosis
- (D) Heterophagy

Q45. BIO

Which set of biophysical characteristics correctly describes eukaryotic intermediate filaments?

- (A) Diameter: 8 to 10 nm; Protein: Vimentin / Keratin; Function: Mechanical tension resistance
- (B) Diameter: 25 nm; Protein: Alpha and beta tubulin; Function: Cilia and flagella motility
- (C) Diameter: 7 nm; Protein: G-actin; Function: Cytoplasmic streaming and cleavage furrows
- (D) Diameter: 15 to 20 nm; Protein: Myosin; Function: ATP-dependent power strokes

Q46. BIO

Nucleoproteins play a primary physiological role in:

- (A) Forming the glycocalyx for self versus non-self cellular recognition
- (B) Packaging, stabilizing, and transmitting hereditary genetic material
- (C) Saltatory conduction of electrical impulses across myelinated axons
- (D) Catalyzing the synthesis of neutral triglycerides in adipocytes

Q47. BIO

If the menstrual cycle of a healthy female begins with the onset of menses on the 10th of July, ovulation in a typical 28-day cycle will most likely occur on:

- (A) 1st of August
- (B) 28th of July
- (C) 24th of July
- (D) 5th of August

Q48. BIO

Which of the following cells is formed directly as a result of reduction division (meiosis I) during gametogenesis?

- (A) Oogonium
- (B) Primary oocyte
- (C) Primary spermatocyte
- (D) Secondary oocyte

Q49. BIO

In garden peas, purple flower color (P) is dominant over white (p), and axial flower position (A) is dominant over terminal (a). If a true-breeding purple axial plant is crossed with a white terminal plant, what is the theoretical probability of obtaining a plant with purple terminal flowers in the F_2 generation?

- (A) $\frac{9}{16}$
- (B) $\frac{1}{16}$
- (C) $\frac{3}{16}$
- (D) $\frac{3}{4}$

Q50. BIO

A woman who is a heterozygous carrier for hemophilia (an X-linked recessive disorder) marries a man who has hemophilia. What is the probability that their male offspring (sons) will be affected by hemophilia?

- (A) 100%
- (B) 50%
- (C) 25%
- (D) 0%

Q51. BIO

Which of the following statements is INCORRECT regarding the human ABO blood group system?

- (A) The inheritance pattern is governed by multiple alleles at a single genetic locus
- (B) Alleles I^A and I^B exhibit complete codominance when expressed together
- (C) The polymorphic alleles do not code for any antigenic surface molecules
- (D) The segregation of ABO alleles follows Mendelian principles

Q52. BIO

Which of the following genetic statements correctly describes androgenic alopecia (pattern baldness)?

- (A) It is an X-linked recessive trait located on the sex chromosomes
- (B) It is a sex-influenced autosomal trait modulated by circulating androgen levels
- (C) A heterozygous male carries the allele without ever showing phenotypic expression
- (D) Homozygous females show identical severe baldness patterns to homozygous males

Q53. BIO

Athletes frequently suffer hamstring strains. Which anatomical statement correctly describes the hamstring muscle group?

- Ⓐ They act primarily as extensor muscles across the knee joint
- Ⓑ They insert distally onto the patellar tendon and tibial tuberosity
- Ⓒ They originate from the ischial tuberosity of the pelvis and the posterior femur
- Ⓓ They originate from the anterior superior iliac spine

Q54. BIO

Which of the following structural features characterizes a skeletal muscle sarcomere in its fully relaxed state?

- Ⓐ Active myosin-binding sites continuously exposed on actin filaments
- Ⓑ A wide, well-defined H-zone centered within the A-band
- Ⓒ High density of active actomyosin cross-bridges
- Ⓓ High concentration of free ionic calcium within the sarcoplasm

Q55. BIO

The children of a laborer do not inherit the hypertrophied skeletal muscles developed by their father through years of manual labor. This observation illustrates which evolutionary principle?

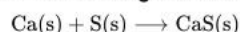
- Ⓐ Natural selection through differential reproductive success
- Ⓑ Malthusian overproduction of offspring leading to a struggle for existence
- Ⓒ Non-inheritance of acquired somatic modifications (Weismann barrier)
- Ⓓ Lamarckian adaptation through the use and disuse of organs

CHEM SECTION: CHEMISTRY

Questions 56 to 95 (40 MCQs)

Q56. CHEM

Calcium reacts with sulfur according to the balanced equation:



If 2.0 g of calcium and 4.0 g of sulfur are allowed to react, what is the theoretical mass of calcium sulfide formed? (Molar masses: Ca = 40.08 g/mol, S = 32.06 g/mol, CaS = 72.14 g/mol)

- (A) 4.6 g
(B) 2.6 g
(C) 3.6 g
(D) 5.3 g

Q57. CHEM

Which of the following gaseous or elemental samples contains the greatest total number of molecules or atoms? (Atomic masses: H = 1, C = 12, N = 14, O = 16, Na = 23)

- (A) 2.0 g of solid sodium metal
(B) 2.0 g of diatomic hydrogen gas (H_2)
(C) 2.0 g of diatomic nitrogen gas (N_2)
(D) 2.0 g of carbon dioxide gas (CO_2)

Q58. CHEM

The value of the azimuthal quantum number (l) for an electron residing in a $4p$ atomic orbital is:

- (A) 0
(B) 1
(C) 2
(D) 3

Q59. CHEM

Which transition element corresponds to the ground-state electron configuration $[\text{Kr}] 5s^2 4d^5$?

- (A) Strontium ($_{38}\text{Sr}$)
(B) Technetium ($_{43}\text{Tc}$)
(C) Ruthenium ($_{44}\text{Ru}$)
(D) Palladium ($_{46}\text{Pd}$)

Q60. CHEM

Choose the permitted (physically allowed) set of quantum numbers for an electron in an atom:

- (A) $n = 3, l = 2, m_l = 0, s = +\frac{1}{2}$
(B) $n = 3, l = 3, m_l = 0, s = -\frac{1}{2}$
(C) $n = 4, l = 3, m_l = +4, s = +\frac{1}{2}$
(D) $n = 4, l = 2, m_l = +3, s = -\frac{1}{2}$

Q61. CHEM

An ideal gas occupies a volume of 10 dm^3 at 10°C . At what temperature will the volume of the gas be halved if the pressure is kept constant?

- (A) 283.15 K
(B) 566.30 K
(C) 141.58 K
(D) 373.15 K

Q62. CHEM

The mathematical relationship between the absolute temperature (T) and the root mean square velocity (c_{rms}) of an ideal gas of molar mass M is given by:

- (A) $c_{\text{rms}} = \sqrt{\frac{3RT}{M}}$
(B) $c_{\text{rms}} = \sqrt{\frac{2RT}{M}}$
(C) $c_{\text{rms}} = \frac{3RT}{2M}$
(D) $c_{\text{rms}} = \sqrt{\frac{8RT}{\pi M}}$

Q63. CHEM

Which of the following unbranched hydrocarbons exhibits the greatest polarizability?

- (A) C_6H_{14} (Hexane)
(B) C_2H_6 (Ethane)
(C) C_4H_{10} (Butane)
(D) C_3H_8 (Propane)

Q64. CHEM

Which of the following solid substances does NOT exhibit a sharp, characteristic molar heat of fusion?

- (A) Sodium chloride (NaCl)
(B) Aluminium oxide (Al_2O_3)
(C) Iron(III) oxide (Fe_2O_3)
(D) Amorphous network silicates (glass)

Q65. CHEM

If the external atmospheric pressure above a liquid is reduced to half its standard value, the boiling point of pure ethanol will be:

- (A) Greater than 78.3°C
(B) Less than 78.3°C
(C) Exactly equal to 78.3°C
(D) Halved to 39.1°C

Q66. CHEM

Solid iodine (I_2) is a poor electrical conductor primarily because:

- (A) It forms a molecular lattice held by weak dispersion forces without free ions or delocalized electrons
(B) It forms an open metallic lattice that scatters charge carriers
(C) Its intramolecular covalent bonds are completely non-polar
(D) It possesses an ionic rock-salt crystal structure

Q67. CHEM

Predict the crystal lattice geometry of cesium chloride (CsCl), which has a cation-to-anion radius ratio (r_+/r_-) of 0.93:

- (A) Tetrahedral with 4 : 4 coordination
(B) Octahedral with 6 : 6 coordination
(C) Body-centered cubic with 8 : 8 coordination
(D) Hexagonal close-packed with 12 coordination

Q68. CHEM

The solubility product constant (K_{sp}) of lead(II) sulfide (PbS) at 25°C is 4.0×10^{-28} . What is the molar solubility (S) of PbS in pure water?

- (A) $4.0 \times 10^{-14} \text{ M}$
(B) $2.0 \times 10^{-14} \text{ M}$
(C) $1.0 \times 10^{-14} \text{ M}$
(D) $2.0 \times 10^{-28} \text{ M}$

Q69. CHEM

Which industrial operating conditions are applied in the Haber process to optimize the equilibrium yield and production rate of ammonia (NH_3)?

- (A) 200 atm and 500°C
- (B) 100 atm and 200°C
- (C) 100 atm and 400°C
- (D) 200 atm and 400°C to 450°C

Q70. CHEM

Which of the following aqueous buffer solutions possesses the HIGHEST pH? (K_a of $\text{CH}_3\text{COOH} = 1.8 \times 10^{-5}$)

- (A) 0.10 M CH_3COOH + 0.01 M CH_3COO^-
- (B) 0.10 M CH_3COOH + 0.05 M CH_3COO^-
- (C) 0.10 M CH_3COOH + 0.10 M CH_3COO^-
- (D) 0.10 M CH_3COOH + 0.15 M CH_3COO^-

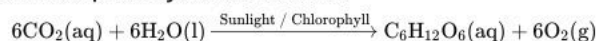
Q71. CHEM

The initial rate of hydrogen gas evolution during the reaction of 1.0 g of zinc with 50 cm^3 of 1.0 M HCl will be fastest when using:

- (A) A single solid 1.0 g zinc rod
- (B) 1.0 g of zinc pellets
- (C) 1.0 g of zinc ribbon strips
- (D) 1.0 g of fine zinc powder

Q72. CHEM

Consider the photosynthetic reaction:



Under conditions of saturating light intensity and excess water, the kinetic order of this photochemical reaction with respect to reactant concentrations is:

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

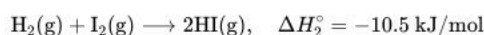
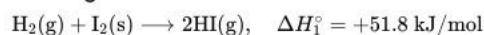
Q73. CHEM

Which of the following reaction mechanisms is consistent with the experimentally observed rate law $\text{Rate} = k[\text{NO}]^2[\text{H}_2]$?

- (A) $2\text{NO} + \text{H}_2 \rightarrow \text{N}_2 + \text{H}_2\text{O}_2$ (slow); $\text{H}_2\text{O}_2 + \text{H}_2 \rightarrow 2\text{H}_2\text{O}$ (fast)
- (B) $\text{NO} + \text{H}_2\text{O} \rightarrow \text{N}_2 + \text{H}_2\text{O}_2$ (slow); $\text{H}_2\text{O}_2 + \text{H}_2 \rightarrow 2\text{H}_2\text{O}$ (fast)
- (C) $2\text{NO} + 2\text{H}_2 \rightarrow \text{N}_2\text{O} + \text{H}_2$ (slow); $\text{N}_2\text{O} + \text{H}_2 \rightarrow \text{H}_2\text{O}_2$ (fast)
- (D) $\text{NO} + \text{NO} \rightarrow \text{N}_2 + \text{O}_2$ (slow); $\text{O}_2 + \text{H}_2 \rightarrow \text{H}_2\text{O}$ (fast)

Q74. CHEM

Given the following thermochemical data:



What is the standard enthalpy of sublimation ($\Delta H_{\text{sub}}^\circ$) of one mole of solid iodine ($\text{I}_2(\text{s}) \rightarrow \text{I}_2(\text{g})$)?

- (A) +41.3 kJ/mol
- (B) +62.3 kJ/mol
- (C) -62.3 kJ/mol
- (D) +36.5 kJ/mol

Q75. CHEM

Which of the following chemical equations represents a standard enthalpy of reaction that is NOT a standard enthalpy of formation (ΔH_f°)?

- (A) $\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$
- (B) $\text{CO}(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g})$
- (C) $\text{C}(\text{graphite}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g})$
- (D) $\text{S}(\text{rhombic}) + \text{O}_2(\text{g}) \rightarrow \text{SO}_2(\text{g})$

Q76. CHEM

Gaseous expansion occurs when carbon dioxide gas is evolved during the reaction between marble chips (CaCO_3) and dilute hydrochloric acid (HCl) in an open container. Under standard thermodynamic sign conventions (IUPAC), the signs for heat exchanged (q) and expansion work done (w) by the system are:

- (A) w is positive, q is negative
- (B) w is negative, q is positive
- (C) q is positive, $w = 0$
- (D) w is negative, q is negative

Q77. CHEM

A zinc rod acts as the cathode when coupled with a magnesium electrode in a standard galvanic cell. This occurs because the standard reduction potential of:

- (A) Zinc is greater (more positive) than that of magnesium
- (B) Zinc is lower (more negative) than that of magnesium
- (C) Zinc is exactly equal to that of magnesium
- (D) Zinc is exactly zero relative to magnesium

Q78. CHEM

Placing a clean iron rod into an aqueous blue solution of copper(II) sulfate (CuSO_4) results in:

- (A) Deposition of metallic copper on the iron rod as iron dissolves
- (B) Immediate precipitation of insoluble elemental iron
- (C) Simultaneous dissolution of copper and iron without electron transfer
- (D) No chemical reaction because copper is more reactive than iron

Q79. CHEM

In chloromethane (CH_3Cl), the experimental C – Cl bond length is 176.7 pm. If the single-bond covalent radius of the chlorine atom is 99.4 pm, what is the covalent radius of the carbon atom?

- (A) 66.3 pm
- (B) 276.1 pm
- (C) 175.4 pm
- (D) 77.3 pm

Q80. CHEM

Which of the following sequences correctly represents the decreasing order of electron affinities among Group 17 halogens?

- (A) $\text{F} > \text{Cl} > \text{Br} > \text{I}$
- (B) $\text{Cl} > \text{F} > \text{Br} > \text{I}$
- (C) $\text{I} > \text{Br} > \text{Cl} > \text{F}$
- (D) $\text{Cl} > \text{Br} > \text{F} > \text{I}$

Q81. CHEM

Which of the following single covalent bonds exhibits the HIGHEST bond dissociation energy?

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

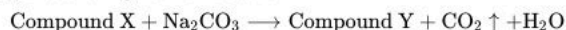
Q82. CHEM

Identify the orbital hybridization state of the central nitrogen atom in a diazonium cation or linear nitrogen chloride cation species represented by $[N \equiv N - Cl]^+$:

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

Q83. CHEM

An unknown organic compound X reacts with sodium carbonate (Na_2CO_3) according to the reaction:



If Compound Y is a sodium salt of a carboxylic acid, Compound X must be:

- (A) $CH_2 = CH - CH_2 - CH_3$
 (B) CH_3CH_2CHO
 (C) CH_3COOCH_3
 (D) CH_3CH_2COOH

Q84. CHEM

Consider the haloform reaction sequence:



If Compound B is a pale yellow antiseptic precipitate of iodoform (CHI_3), identify starting Compound A:

- (A) Acetone (CH_3COCH_3)
 (B) Ethanoic acid (CH_3COOH)
 (C) Acetamide (CH_3CONH_2)
 (D) Acetic anhydride ($(CH_3CO)_2O$)

Q85. CHEM

Which of the following aliphatic carboxylic acids has the HIGHEST melting point?

- (A) Ethanoic acid (CH_3COOH)
 (B) Propanoic acid (CH_3CH_2COOH)
 (C) Butanoic acid ($CH_3(CH_2)_2COOH$)
 (D) Pentanoic acid ($CH_3(CH_2)_3COOH$)

Q86. CHEM

Which of the following organic compounds possesses the SHORTEST carbon-heteroatom (C – O or C – N) bond length?

- (A) Methylamine (CH_3NH_2)
 (B) Formamide ($HCONH_2$)
 (C) Formic acid ($HCOOH$)
 (D) Ethanol (CH_3CH_2OH)

Q87. CHEM

Identify the alkene that produces only a SINGLE type of aldehyde upon ozonolysis followed by reductive cleavage with Zn/H_2O :

- (A) 1-pentene
 (B) 2-methylpropene
 (C) 2-butene
 (D) 2,3-dimethyl-2-butene

Q88. CHEM

What is the correct order of INCREASING reactivity of carbonyl compounds toward nucleophilic addition reactions?

- (A) $HCHO < CH_3CHO < CH_3CH_2CHO < CH_3COCH_3$
 (B) $CH_3CHO < CH_3COCH_3 < CH_3CH_2CHO < HCHO$
 (C) $CH_3CH_2CHO < CH_3COCH_3 < HCHO < CH_3CHO$
 (D) $CH_3COCH_3 < CH_3CH_2CHO < CH_3CHO < HCHO$

Q89. CHEM

Bakelite, an important thermosetting cross-linked polymer, is manufactured industrially through the step-growth condensation polymerization of:

- (A) Phenol and formaldehyde in the presence of a dilute acid or base catalyst
 (B) Phenol and sodium hydroxide under anhydrous conditions
 (C) Phenol and concentrated sulfuric acid at elevated temperatures
 (D) Phenol and acetyl chloride in the presence of anhydrous aluminium chloride

Q90. CHEM

What is the correct increasing order of reactivity of isomeric hexanols toward nucleophilic substitution involving C – O bond cleavage?

- (A) 2-methyl-2-pentanol < 3-methyl-2-pentanol < 2-methyl-1-pentanol
 (B) 3-methyl-2-pentanol < 2-methyl-1-pentanol < 2-methyl-2-pentanol
 (C) 2-methyl-1-pentanol < 3-methyl-2-pentanol < 2-methyl-2-pentanol
 (D) 2-methyl-2-pentanol < 2-methyl-1-pentanol < 3-methyl-2-pentanol

Q91. CHEM

Which of the following isomeric pentyl alcohols reacts most rapidly with Lucas reagent (anhydrous $ZnCl_2$ in concentrated HCl) at room temperature?

- (A) 2-butanol
 (B) 2-methyl-1-butanol
 (C) 2-methyl-2-butanol
 (D) 2,2-dimethyl-1-propanol

Q92. CHEM

Which of the following substituted benzene derivatives undergoes electrophilic aromatic sulfonation most readily?

- (A) Benzene
 (B) Chlorobenzene
 (C) Nitrobenzene
 (D) Toluene

Q93. CHEM

Which of the following alkenes exhibits geometrical (cis-trans) isomerism?

- (A) 3-methyl-1-butene
 (B) Methylcyclopentane
 (C) 2,3-dimethyl-2-butene
 (D) 3-methyl-2-pentene

Q94. CHEM

What is the correct sequence of INCREASING first ionization energies for the third-period elements sodium, magnesium, aluminium, and silicon?

- (A) $Na < Al < Mg < Si$
 (B) $Na < Mg < Al < Si$
 (C) $Mg < Al < Si < Na$
 (D) $Al < Si < Na < Mg$

Q95. CHEM

Which of the following alkaline earth metal carbonates undergoes thermal decomposition most readily upon mild heating?

- (A) Barium carbonate (BaCO_3)
 - (B) Magnesium carbonate (MgCO_3)
 - (C) Beryllium carbonate (BeCO_3)
 - (D) Strontium carbonate (SrCO_3)
-

PHY SECTION: PHYSICS

Questions 96 to 135 (40 MCQs)

Q96. PHY

At what angle between the applied force vector and the displacement vector will the mechanical work done be exactly 50% of its maximum possible value?

- (A) 30°
- (B) 60°
- (C) 90°
- (D) 45°

Q97. PHY

What is the average power output of an industrial electric motor that performs 64×10^6 J of mechanical work in 8.0 seconds?

- (A) 8.0 kW
- (B) 6.0 MW
- (C) 8.0 MW
- (D) 512 MW

Q98. PHY

The mathematical relationship between kinetic energy (E_k) and linear momentum (p) for a particle of mass m moving at non-relativistic speeds is:

- (A) $E_k = \frac{p}{2m}$
- (B) $E_k = \frac{2p}{m^2}$
- (C) $E_k = \frac{p^2}{m^2}$
- (D) $E_k = \frac{p^2}{2m}$

Q99. PHY

When a dolphin leaps straight out of the water, it possesses high kinetic energy at the surface. At the absolute apex (highest point) of its vertical leap, its energy is primarily in the form of:

- (A) Kinetic energy
- (B) Gravitational potential energy
- (C) Elastic strain potential energy
- (D) Chemical bond energy

Q100. PHY

The absolute gravitational potential energy of a mass m at a distance r from the center of the Earth is given by $U_g = -\frac{GmM_e}{r}$. The negative sign in this equation signifies that:

- (A) The gravitational force field is repulsive at all distances
- (B) The gravitational field is attractive, forming a bound system
- (C) Gravitational potential energy increases as the mass approaches the Earth
- (D) The mass has escaped Earth's gravitational pull

Q101. PHY

The instantaneous velocity of an object undergoing uniform circular motion at constant speed is:

- (A) Constant in both magnitude and direction
- (B) Variable due to continuous change in direction
- (C) Identically zero at all points along the path
- (D) Directed radially inward toward the center of curvature

Q102. PHY

During rapid vehicular deceleration, wearing seat belts significantly reduces occupant injury primarily because the seat belt:

- (A) Increases the net momentum change required to bring the occupant to rest
- (B) Applies a perpendicular normal force that deflects kinetic energy
- (C) Applies an opposing restraining force that lengthens deceleration time, reducing impact force
- (D) Completely eliminates the occupant's inertia of motion

Q103. PHY

A ball possessing an initial momentum of $+8.0 \text{ kg} \cdot \text{m/s}$ strikes a rigid wall perpendicularly and rebounds elastically along the same line without loss of kinetic energy. What is the change in linear momentum of the ball?

- (A) $+4.0 \text{ N} \cdot \text{s}$
- (B) $-8.0 \text{ N} \cdot \text{s}$
- (C) $-16.0 \text{ N} \cdot \text{s}$
- (D) $0 \text{ N} \cdot \text{s}$

Q104. PHY

In projectile motion over level ground, at what launch angle (θ) will the maximum height reached (H) be exactly equal to half of the total horizontal range (R)?

- (A) 75°
- (B) 45°
- (C) 60°
- (D) 63°

Q105. PHY

An athlete runs along a circular track that has a diameter of 20 m. If she traverses a total distance of 180 m along the perimeter, what is her total angular displacement in radians?

- (A) 18 radians
- (B) 10 radians
- (C) 9 radians
- (D) 36 radians

Q106. PHY

The angular displacement swept by the minute hand of a standard clock in exactly one minute of time is:

- (A) 6°
- (B) 12°
- (C) 30°
- (D) 0.5°

Q107. PHY

To determine the vector direction of angular displacement for a rotating body, one should apply the right-hand rule by:

- (A) Grasping the axis of rotation with the right hand so curled fingers follow the rotation; the thumb points along the displacement
- (B) Grasping the axis of rotation with the left hand with fingers curling counter-rotationally
- (C) Aligning the right thumb tangent to the circular trajectory with fingers along the radius
- (D) Pointing the right index finger toward the center of curvature and thumb vertically

Q108. PHY

A particle traverses a circular path of radius 200 cm at a constant linear speed of 20 m/s. What is its angular velocity?

- (A) 2.0 rad/s
- (B) 4.0 rad/s
- (C) 200 rad/s
- (D) 10 rad/s

Q109. PHY

By standard vector convention in physics, an anti-clockwise (counter-clockwise) rotation in the plane of the page corresponds to an angular displacement that is:

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

Q110. PHY

The speed of sound in solid steel is substantially greater than in air primarily because:

- (A) The density of steel is much lower than the density of air
- (B) Gases lack restoring forces for mechanical disturbance
- (C) The ratio of modulus of elasticity to density (E/ρ) is far larger in steel than in air
- (D) Sound travels as transverse waves in air but longitudinal waves in steel

Q111. PHY

A block of mass 10 kg attached to an ideal horizontal spring oscillates on a frictionless surface. If the maximum displacement (amplitude) is 20 cm and the spring constant is 20 N/m, what is the maximum acceleration of the block?

- (A) 2.0 m/s^2
- (B) 4.0 m/s^2
- (C) 2.2 m/s^2
- (D) 0.4 m/s^2

Q112. PHY

A person with normal hearing can perceive acoustic frequencies ranging from 20 Hz to 20 kHz. Assuming the speed of sound in air is 340 m/s, what is the MAXIMUM wavelength of sound audible to the human ear?

- (A) 17 m
- (B) 17 mm
- (C) 17 cm
- (D) 17 km

Q113. PHY

Crystalline sodium chloride (NaCl) dissolves rapidly in liquid water primarily because of water's:

- (A) Low dielectric constant that concentrates interionic charges
- (B) High dielectric constant that weakens electrostatic attractions between lattice ions
- (C) Low surface tension that breaks lattice bonds mechanically
- (D) Ability to act as an electron-pair acceptor

Q114. PHY

Theoretically, the time required for an ideal capacitor in an RC series circuit to achieve a 100% fully charged state from a DC voltage source is:

- (A) Exactly one time constant (1τ)
- (B) Exactly two time constants (2τ)
- (C) Approximately five time constants (5τ)
- (D) Infinite time ($t \rightarrow \infty$)

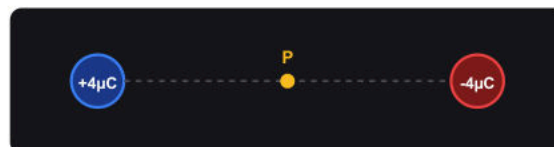
Q115. PHY

What is the magnitude of the electric field intensity at a radial distance of 10 cm from an isolated point charge of $+2.0 \mu\text{C}$ in free space?

- (A) $1.8 \times 10^6 \text{ N/C}$
- (B) $1.8 \times 10^5 \text{ N/C}$
- (C) $1.8 \times 10^4 \text{ N/C}$
- (D) $1.8 \times 10^3 \text{ N/C}$

Q116. PHY

Two equal and opposite point charges, $+4.0 \mu\text{C}$ and $-4.0 \mu\text{C}$, are separated by a distance $2d$ in a vacuum. At the exact midpoint P along the line connecting them:



- (A) $V = 0, E \neq 0$
- (B) $V \neq 0, E = 0$
- (C) $V = 0, E = 0$
- (D) $V \neq 0, E \neq 0$

Q117. PHY

A thermodynamic process in which all heat energy added to a closed system is used exclusively to increase its internal energy is known as an:

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

Q118. PHY

What is the phase difference between alternating voltage and alternating current in an ideal AC circuit containing only a pure capacitor?

- (A) Current leads voltage by $\frac{\pi}{2}$ radians
- (B) Voltage and current are in phase
- (C) Voltage leads current by π radians
- (D) Current lags voltage by $\frac{\pi}{2}$ radians

Q119. PHY

A particle carrying a net electric charge of 1.0 C moves through an electric potential difference of 5.0 V. The kinetic energy acquired by the particle is:

- (A) $5.0 \times 10^{-19} \text{ J}$
- (B) $5.0 \times 10^{19} \text{ J}$
- (C) 5.0 J
- (D) 0.20 J

Q120. PHY

Which of the following $I - V$ characteristic curves represents a non-ohmic conductor (such as an NTC thermistor) whose electrical resistance DECREASES as the electric current increases?



- (A) A linear straight line passing through the origin with fixed slope
- (B) A curve that bends toward the voltage axis such that $\frac{dI}{dV}$ decreases
- (C) A curve that bends upward toward the current axis such that $\frac{dI}{dV}$ increases
- (D) A horizontal line showing current independent of voltage

Q121. PHY

Determine the equivalent electrical resistance between terminals A and B for the circuit network shown below:



- (A) 3.0Ω
- (B) $\frac{1}{3} \Omega$
- (C) 1.0Ω
- (D) $\frac{2}{3} \Omega$

Q122. PHY

A household operates four electric fans of 100 W each and two lighting bulbs of 100 W each for 2.0 hours every day. What is the total electrical energy consumed over a 30-day billing month?

- (A) 4.0 kWh
- (B) 12.0 kWh
- (C) 18.0 kWh
- (D) 36.0 kWh

Q123. PHY

A straight wire of length 100 cm is placed perpendicular to a uniform magnetic field of 0.50 T. If the wire carries a steady electric current of 10 A, the magnetic force exerted on the wire is:

- (A) 50 N
- (B) 5.0 N
- (C) 10 N
- (D) 0.50 N

Q124. PHY

Which class of materials possesses a negative temperature coefficient of electrical resistance (NTC)?

- (A) Metallic conductors
- (B) Semiconductors
- (C) Standard resistance alloys (e.g., Manganin)
- (D) Superconductors below critical temperature

Q125. PHY

If the electric field intensity between the plates of an isolated parallel-plate capacitor is doubled, the total electrostatic energy stored in the capacitor becomes:

- (A) Double
- (B) Half
- (C) Four times (Quadruple)
- (D) Eight times

Q126. PHY

The horizontal range of a projectile fired with initial speed v_0 on level ground is maximized when the launch angle satisfies:

- (A) $\sin \theta = 1$
- (B) $\sin 2\theta = 1$
- (C) $\sin \theta = 0$
- (D) $\sin 2\theta = 0$

Q127. PHY

How many degrees of arc correspond to an angular displacement of $\frac{2\pi}{5}$ radians?

- (A) 36°
- (B) 50°
- (C) 72°
- (D) 90°

Q128. PHY

An ideal step-up transformer connected to a 220 V AC supply line delivers 22 A at an output voltage of 1800 V. Assuming 100% electrical efficiency, what current is drawn by the primary coil from the supply line?

- (A) 180 A
- (B) 22 A
- (C) 50 A
- (D) 200 A

Q129. PHY

In an AC-to-DC power supply circuit, which electronic component performs rectification?

- (A) Step-down iron-core transformer
- (B) Semiconductor pn-junction diode
- (C) Electrolytic smoothing capacitor
- (D) Zener voltage regulator diode

Q130. PHY

The positron emission decay of radioactive fluorine-18 is represented by the nuclear reaction:



Identify the emitted subatomic particles x and y :

- (A) $x = \alpha$ -particle, $y = \beta^-$ -particle
- (B) $x = \beta^-$ -particle, $y = \gamma$ -photon
- (C) $x = \text{neutron}$, $y = \text{antineutrino}$
- (D) $x = \text{positron } (\beta^+)$, $y = \text{electron neutrino } (\nu_e)$

Q131. PHY

One roentgen equivalent man (rem) is related to the gray (Gy) and relative biological effectiveness (RBE) by:

- (A) $1 \text{ rem} = \frac{0.01 \text{ Gy}}{\text{RBE}}$
- (B) $1 \text{ rem} = 0.01 \text{ Gy} \times \text{RBE}$
- (C) $1 \text{ rem} = 0.01 \text{ RBE}$
- (D) $1 \text{ rem} = 1.0 \text{ Gy} \times \text{RBE}$

Q132. PHY

One radiation absorbed dose (rad) corresponds to an energy absorption per unit mass of biological tissue equal to:

- (A) 0.01 J/kg
- (B) 0.01 kJ/g
- (C) 0.01 J
- (D) 1.0 J/kg

Q133. PHY

A 60 kg individual receives a whole-body equivalent dose of 200 rem from radiation having an RBE factor of 10. What is the total energy absorbed by the individual's body?

- (A) 9.0 J
- (B) 8.0 J
- (C) 12.0 J
- (D) 120 J

Q134. PHY

Which of the following biological consequences is classified strictly as a somatic effect of ionizing radiation?

- (A) Point mutations in sperm DNA
- (B) Hereditary malformations in future generations
- (C) Acute skin erythema and radiation burns in the exposed individual
- (D) Aneuploidy in maternal oocytes prior to fertilization

Q135. PHY

On average, a human being receives an annual natural background radiation equivalent dose of approximately:

- (A) 1.0 to 2.0 mSv
- (B) 20 mSv
- (C) 100 mSv
- (D) 1.0 Sv

ENG SECTION: ENGLISH

Questions 136 to 150 (15 MCQs)

Q136. ENG

Identify the grammatical function of the underlined modal in the sentence below:

"The commercial flight ought to be landing in a few minutes."

- (A) Linking verb
- (B) Modal auxiliary
- (C) Phrasal verb
- (D) Transitive verb

Q137. ENG

In the sentence, "During the heavy rainstorm, the afternoon sky grew dark," the underlined verb functions as a:

- (A) Non-finite verb
- (B) Transitive verb
- (C) Intransitive action verb
- (D) Linking (copular) verb

Q138. ENG

In the sentence, "His exceptional courage brought him honour," the underlined verb is classified as:

- (A) Intransitive
- (B) Ditransitive
- (C) Complex transitive
- (D) Copular

Q139. ENG

In the sentence, "The teacher assigned the students an assignment to be completed during vacation," the underlined verb is:

- (A) Monotransitive
- (B) Ditransitive
- (C) Complex transitive
- (D) Intransitive

Q140. ENG

In the traditional proverb, "Of two evils choose the less," the underlined word functions as an adjective in the:

- (A) Comparative degree
- (B) Positive degree
- (C) Superlative degree
- (D) Distributive class

Q141. ENG

In the interrogative sentence, "Are there any mango trees in this garden?", the underlined word functions as an:

- (A) Adjective of quantity / indefinite determiner
- (B) Adjective of quality
- (C) Relative pronoun
- (D) Reciprocal pronoun

Q142. ENG

In the sentence, "This is the very thing we want," the underlined word functions as an:

- (A) Emphatic pronoun
- (B) Emphasizing adjective
- (C) Reflexive pronoun
- (D) Degree adverb modifying a verb

Q143. ENG

In the warning, "Don't be in such a hurry," the underlined word is used as an adjective of:

- (A) Definite number
- (B) Manner and degree / emphasizing determiner
- (C) Distributive reference
- (D) Interrogation

Q144. ENG

Fill in the blank with the appropriate verb form indicating the **Past Perfect Continuous** tense:

"He _____ home from work regularly since he joined his office."

- (A) Had walked
- (B) Has been walking
- (C) Walked
- (D) Had been walking

Q145. ENG

"All desire wealth, and some acquire it." This compound sentence exemplifies which grammatical tense across both coordinate clauses?

- (A) Present Indefinite (Simple Present)
- (B) Past Indefinite
- (C) Present Perfect
- (D) Simple Future

Q146. ENG

Identify the sentence that contains an **INCORRECT** grammatical structure:

- (A) Justice, as well as mercy, allows it.
- (B) In him, was centered piety and wisdom.
- (C) The wages of sin is death.
- (D) Fire and water do not agree.

Q147. ENG

"If I were a doctor, I would serve humanity." This sentence is an example of which type of conditional construction?

- (A) Zero conditional
- (B) Type II conditional (Second conditional)
- (C) Type I conditional (First conditional)
- (D) Type III conditional (Third conditional)

Q148. ENG

Choose the sentence that is grammatically and conditionally structured correctly:

- (A) If we had found him earlier, we would have saved his life.
- (B) If we had found him earlier, we would saved his life.
- (C) If we had found him earlier, we will have saved his life.
- (D) If we found him earlier, we would have saved his life.

Q149. ENG

"Owing to his bad luck, he got into an accident on the eve of his examination." What structural type of sentence is this?

- (A) Complex sentence
- (B) Simple sentence
- (C) Compound sentence
- (D) Compound-complex sentence

Q150. ENG

Which of the following sentences exhibits correct punctuation and possessive apostrophe placement?

- Ⓐ My siblings bags were stolen by the boys chief whose gun color is black.
- Ⓑ My siblings bags were stolen by the boys chief, whose gun's color is black.
- Ⓒ "My siblings' bags were stolen by the chief of the boys, whose gun was black."
- Ⓓ "My siblings bags were stolen by the chief of the boys, whose gun was black."

OFFICIAL VERIFIED ANSWER KEY

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

SUBJECT-WISE PERFORMANCE BREAKDOWN

SUBJECT	MAX	YOUR SCORE	ACCURACY
Biology	55		----- %
Chemistry	40		----- %
Physics	40		----- %
English	15		----- %
TOTAL	150	-----	----- %

NUMS ADMISSION MERIT FORMULA

Official Weightage Law:

- NUMS Component (50%): (Your Score / 150) × 50
- FSc / HSSC Component (40%): (FSc Marks / 1100) × 40
- Matric / SSC Component (10%): (Matric Marks / 1100) × 10

Estimated NUMS Merit Aggregate: ----- %

PROPOLIS COGNITIVE ERROR AUTOPSIES

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

Question #1 Key: (C)

BIOLOGY
01. Cell

Which function cannot be attributed to plasma membrane lipids?

CORE CONCEPT & DERIVATION

Plasma membrane lipids provide a dynamic hydrophobic barrier, structural stability, and cell identity markers. Catalytic control of metabolic pathways across membranes is performed exclusively by membrane-bound enzymatic proteins.

Formula / Rule / Reaction:

Factual recall / Membrane Biochemistry.

Solution:

- Membrane lipids consist of phospholipids, glycolipids, and sterols (cholesterol).
- Cholesterol modulates bilayer fluidity and mechanical flexibility across temperature ranges.
- Glycolipids project carbohydrate chains into the extracellular space to form cell identity markers.
- Enzymes (integral and peripheral proteins), not lipids, catalyze and regulate metabolic reactions across membranes.

Why other options are incorrect:

- **Option A:** Glycolipids on the outer membrane leaflet form antigens that recognize non-self cells.
- **Option B:** Unsaturated hydrocarbon tails and cholesterol regulate phospholipid packing and flexibility.
- **Option D:** Inositol phospholipids (such as PIP₂) are cleavage substrates for signaling cascades.

Question #2 Key: (A)

BIOLOGY
01. Cell

Follow the correct secretory route of pepsinogen produced by gastric chief cells:

CORE CONCEPT & DERIVATION

Secretory proteins synthesized by bound ribosomes on the rough endoplasmic reticulum traverse the endomembrane system for folding, post-translational modification, and packaging before exocytosis.

Formula / Rule / Reaction:

Ribosomes (RER) → Lumen (ER) → Transport Vesicles → Golgi Cisternae → Secretory Vesicles → ~~Solutions~~

Solution:

- Pepsinogen is synthesized by ribosomes attached to the rough endoplasmic reticulum (RER).
- The polypeptide enters the ER lumen and moves toward smooth/transitional exit sites.
- Transport vesicles carry the protein to the cis-face of the Golgi complex for glycosylation and sorting.
- Mature pepsinogen is packaged into zymogen granules (secretory vesicles) budding from the trans-Golgi.

Why other options are incorrect:

- **Option B:** Translation of secretory enzymes begins on the RER, not the smooth endoplasmic reticulum.
- **Option C:** Mitochondria generate ATP and do not participate in the vesicular secretory pathway.
- **Option D:** This sequence reverses the directional vector of cellular protein trafficking.

Question #3 Key: (C)

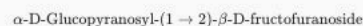
BIOLOGY
02. Biomolecules

The low chemical reactivity of sucrose relative to monosaccharides is due to its:

CORE CONCEPT & DERIVATION

Reducing reactivity in sugars requires a free hemiacetal or hemiketal group capable of mutarotation into an open-chain carbonyl form. When both anomeric carbons participate in a glycosidic bond, the sugar becomes non-reducing and chemically stable.

Formula / Rule / Reaction:



Solution:

- Sucrose is formed by linking the anomeric C-1 of α -D-glucose to the anomeric C-2 of β -D-fructose.
- Because both anomeric carbons are tied up in the $\alpha(1 \rightarrow 2)$ glycosidic bond, neither ring can open.
- Without a free aldehyde or ketone functional group, sucrose cannot reduce mild oxidizing agents, making it chemically unreactive.

Why other options are incorrect:

- **Option A:** High water solubility does not prevent chemical oxidation of carbohydrates.
- **Option B:** Monosaccharides are also polar and water-soluble yet remain highly reactive.
- **Option D:** Sucrose contains an acetal/glycosidic bond, not an amino acid peptide linkage.

Question #4 Key: (B)

BIOLOGY
02. Biomolecules

Sucrose is used as a transport carbohydrate in vascular plants instead of glucose because:

CORE CONCEPT & DERIVATION

Phloem translocation requires a transport carbohydrate that is highly soluble yet metabolically unreactive, preventing unwanted chemical reactions and enzymatic breakdown during long-distance transport.

Formula / Rule / Reaction:

Factual recall / Plant Physiology.

- Glucose contains a reactive free aldehyde group that readily interacts with cellular components and enzymes.
- Sucrose is a non-reducing disaccharide with protected anomeric centers.
- Its non-reducing structure prevents oxidation and premature metabolic degradation inside sieve tube elements.

Why other options are incorrect:

- **Option A:** Sucrose is highly water-soluble, which is necessary for phloem mass flow.
- **Option C:** Sucrose remains chemically intact throughout translocation and does not form starch in transit.
- **Option D:** Loading sucrose actively decreases the solute potential, generating hydrostatic pressure.

Question #5 Key: (A)BIOLOGY
05. Acellular Life

Coronavirus is an enveloped virus. Alcohol-based hand sanitizers and surface cleaners were wide...

CORE CONCEPT & DERIVATION

Enveloped viruses derive an outer lipid bilayer from host cellular membranes. Alcohols, detergents, and extreme pH shifts solubilize lipids and denature surface glycoproteins, destroying viral infectivity.

Formula / Rule / Reaction:

Qualitative concept / Virology.

Solution:

- SARS-CoV-2 is encased in a host-derived phospholipid bilayer envelope embedded with spike proteins.
- Alcohols (60% to 80% ethanol/isopropanol) disrupt lipid-lipid hydrophobic interactions.
- Detergents and pH variations dissolve the envelope and denature structural spike proteins, preventing host entry.

Why other options are incorrect:

- **Option B:** Coronaviruses are heat-labile, but cleaners act chemically rather than thermally.
- **Option C:** The positive-sense ssRNA genome is internal and is not the direct target of rapid solvent action.
- **Option D:** Viruses are acellular particles without cytosolic osmotic tonicity.

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

Proteins exhibiting a tertiary structure are primarily responsible for:

CORE CONCEPT & DERIVATION

Tertiary protein structure results from complex three-dimensional folding of a single polypeptide chain, forming globular proteins that perform biochemical functions such as catalysis, transport, and hormonal signaling.

Formula / Rule / Reaction:

Qualitative concept / Biochemistry.

Solution:

- Globular proteins possess precise three-dimensional tertiary conformations stabilized by hydrophobic interactions, hydrogen bonds, and disulfide links.
- Peptide hormones (e.g., insulin, glucagon, growth hormone) rely on their tertiary conformation to fit specific cell surface receptors.
- Structural fibers (keratin, collagen) are typically fibrous proteins dominated by repetitive secondary structures.

Why other options are incorrect:

- **Option B:** The skin barrier consists of keratin, an insoluble fibrous structural protein.
- **Option C:** Bone and connective tissue matrices are reinforced by triple-helical collagen fibers.
- **Option D:** Hair fibers are composed of alpha-keratin bundles functioning as structural secondary elements.

Question #7 Key: (C)BIOLOGY
02. Biomolecules

Chemical rebonding is used to straighten curly hair. Which chemical bond is targeted and reform...

CORE CONCEPT & DERIVATION

The natural curliness of hair depends on the spatial arrangement of covalent disulfide cross-links between cysteine residues in keratin filaments. Altering these bridges changes hair shape permanently.

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

- Keratin polypeptide chains are stabilized by covalent disulfide bonds (–S–S–).
- A reducing agent (ammonium thioglycolate) breaks disulfide bonds to form free sulfhydryl (–SH) groups.
- Hair is then mechanically straightened on hot plates.
- An oxidizing neutralizer (hydrogen peroxide) oxidizes adjacent sulfhydryl groups to form new disulfide cross-links.

Why other options are incorrect:

- **Option A:** Hydrolyzing peptide bonds would degrade the primary structure of keratin and destroy hair fibers.
- **Option B:** Ionic salt bridges are weak ionic associations disrupted temporarily by water or pH shifts.
- **Option D:** Phosphodiester bonds form the backbone of nucleic acids and are absent in hair keratin.

Question #8 Key: (D)BIOLOGY
03. Enzymes

Ions of heavy metals are harmful to living organisms primarily because of their ability to:

CORE CONCEPT & DERIVATION

Heavy metal cations (such as Pb^{2+} , Hg^{2+} , Cd^{2+} , and Ag^{+}) have high affinities for electron-rich functional groups, especially thiol/sulfhydryl groups, in cellular proteins.

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

- Heavy metal ions bind strongly to sulfhydryl (–SH), amino, and carboxyl groups on protein side chains.
- This binding disrupts native disulfide bridges and salt bridges within tertiary structures.
- As a result, critical cellular enzymes and structural proteins precipitate and undergo irreversible denaturation.

Why other options are incorrect:

- **Option A:** Direct enzymatic cleavage of phosphodiester backbones is carried out by nucleases, not metal ions.
- **Option B:** Heavy metal toxicity generally suppresses rather than accelerates metabolic pathways.
- **Option C:** Glycosidic bond hydrolysis is catalyzed by specific glycosidases or strong hot acids.

Question #9 Key: (C)BIOLOGY
04. Bioenergetics

Choose the option showing the correct labeling of inputs and outputs in the generalized photosynthesis...

CORE CONCEPT & DERIVATION

Photosynthesis comprises two interconnected phases: the thylakoid light-dependent reactions that split water and release oxygen, and the stroma-localized Calvin cycle that fixes carbon dioxide into triose sugars.

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

- Input **A** enters the light reactions and undergoes photolysis: H_2O .
- Input **B** enters the light-independent Calvin cycle for carboxylation: CO_2 .
- Output **C** is released by the light reactions from water splitting: O_2 .
- Output **D** is synthesized in the stroma by the Calvin cycle: Sugar (triose phosphate/glucose).

Why other options are incorrect:

- **Option A:** Inverts the primary gas inputs; CO_2 enters the stroma, while H_2O feeds the thylakoids.
- **Option B:** Labels sugar as a Calvin cycle input rather than its primary product.
- **Option D:** Lists O_2 as a substrate rather than a byproduct of the oxygen-evolving complex.

Question #10 Key: (D)BIOLOGY
04. Bioenergetics

Which mechanism would be directly compromised in the absence of the cytochrome complex during t...

CORE CONCEPT & DERIVATION

The cytochrome b_6f complex acts as an intermediate electron carrier between Photosystem II and Photosystem I. It couples electron transport with proton translocation from the stroma into the thylakoid lumen, producing a proton-motive force.

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

- Electrons from P_{680} travel via pheophytin and plastoquinone to the cytochrome b_6f complex.
- Cytochrome b_6f mediates the Q-cycle, pumping protons across the membrane into the lumen.
- Without this complex, the proton electrochemical gradient is severely depleted, impairing photophosphorylation by ATP synthase.

Why other options are incorrect:

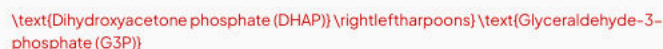
- **Option A:** Water photolysis is catalyzed by the manganese-containing oxygen-evolving complex on Photosystem II.
- **Option B:** P_{680} excitation is driven directly by photons absorbed by light-harvesting pigments.
- **Option C:** Light harvesting by carotenoids depends on pigment resonance transfer, not electron carrier complexes.

Question #11 Key: (A)BIOLOGY
04. Bioenergetics

During glycolysis, an enzymatic isomerization reaction takes place in the interconversion of:

CORE CONCEPT & DERIVATION

Isomerases catalyze intramolecular rearrangements without adding or removing atoms. In the preparatory phase of glycolysis, triose phosphate isomerase converts a ketose into an aldose to keep both triose halves in the mainstream pathway.

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

- Aldolase cleaves fructose-1,6-bisphosphate into two triose isomers: DHAP (ketose) and G3P (aldose).
- Only G3P can be directly oxidized in step 6 by glyceraldehyde-3-phosphate dehydrogenase.
- Triose phosphate isomerase catalyzes the reversible conversion of DHAP to G3P.

Why other options are incorrect:

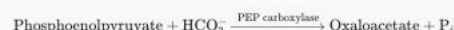
- **Option B:** G3P and fructose-6-phosphate differ in carbon chain length (3C versus 6C); their interconversion involves condensation/cleavage.
- **Option C:** Conversion of PEP to pyruvate is a substrate-level phosphorylation catalyzed by pyruvate kinase.
- **Option D:** Fructose-6-phosphate and 3-phosphoglycerate are separated by multiple phosphorylation and cleavage reactions.

Question #12 Key: (C)BIOLOGY
04. Bioenergetics

The presence of PEP carboxylase in [Formula] plants enables them to avoid photorespiration beca...

CORE CONCEPT & DERIVATION

Photorespiration occurs when Rubisco binds O_2 instead of CO_2 . C_4 plants avoid this problem by using phosphoenolpyruvate (PEP) carboxylase in their mesophyll cells, an enzyme with zero oxygenase activity.

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

- PEP carboxylase has a high affinity for bicarbonate (HCO_3^-) and does not bind O_2 .
- It fixes carbon into 4-carbon oxaloacetate even when internal CO_2 levels are very low.
- Malate is shuttled to bundle-sheath cells and decarboxylated, maintaining high CO_2 around Rubisco and preventing photorespiration.

Why other options are incorrect:

- **Option A:** Avoiding photorespiration is due to enzyme specificity for CO_2 , not just enzyme quantity.
- **Option B:** Rubisco is still present in bundle-sheath cells where the Calvin cycle operates.
- **Option D:** PEP carboxylase does not consume oxygen; oxygen consumption is the defining feature of photorespiration.

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

Fats and proteins can both be used as respiratory fuels. Which molecule serves as the common in...

CORE CONCEPT & DERIVATION

Metabolic pathways for carbohydrates, lipids, and proteins converge on central two-carbon units carried by coenzyme A, which enter the mitochondrial tricarboxylic acid (TCA) cycle.

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

- Fatty acid β -oxidation cleaves 2-carbon units to yield acetyl-CoA directly in the mitochondrial matrix.
- Deaminated ketogenic amino acids and several glucogenic amino acids are also converted into acetyl-CoA.
- Acetyl-CoA condenses with oxaloacetate to form citrate, entering the Krebs cycle.

Why other options are incorrect:

- Option B:** Even-chain fatty acid oxidation yields acetyl-CoA directly without forming pyruvate.
- Option C:** Glycerol from fats can enter glycolysis as G3P, but fatty acid hydrocarbon chains bypass this step entirely.
- Option D:** Lactate is an end product of anaerobic glycolysis, not a normal intermediate of lipid oxidation.

Question #14 Key: (D)BIOLOGY
05. Acellular Life

Which of the following viruses possesses a double-stranded DNA (dsDNA) genome?

CORE CONCEPT & DERIVATION

Viruses are classified into Baltimore groups based on their genome composition (dsDNA, ssDNA, dsRNA, or ssRNA) and pathway to mRNA.

Formula / Rule / Reaction:

Factual recall / Virology Taxonomy.

Solution:

- Smallpox virus (Variola virus, family Poxviridae) contains a large linear double-stranded DNA genome.
- Rubella virus belongs to Matonaviridae and possesses a positive-sense single-stranded RNA (+ssRNA) genome.
- Influenza virus (Orthomyxoviridae) contains a segmented negative-sense single-stranded RNA (-ssRNA) genome.
- HIV (Retroviridae) is an enveloped virus containing two copies of single-stranded positive-sense RNA.

Why other options are incorrect:

- Option A:** Rubella has a single-stranded RNA genome.
- Option B:** Influenza has an 8-segment single-stranded RNA genome.
- Option C:** HIV contains single-stranded RNA that is reverse-transcribed into DNA during infection.

Question #15 Key: (B)BIOLOGY
03. Enzymes

An enzyme is capable of acting on a wide range of structurally related substrates. Which of the...

CORE CONCEPT & DERIVATION

Enzymes with broad substrate specificity (group specificity) have flexible active sites that undergo conformational adjustments upon substrate binding, as described by Koshland's induced-fit model.

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

- In the induced-fit model, the active site is flexible rather than rigid.
- Binding of related chemical substrates induces conformational adjustments that properly align catalytic groups.
- This flexibility allows one enzyme (e.g., hexokinase) to phosphorylate multiple related hexose sugars.

Why other options are incorrect:

- Option A:** A rigid active site corresponds to Fischer's lock-and-key model, which produces strict absolute specificity.
- Option C:** All active enzymes require precise tertiary or quaternary protein conformations.
- Option D:** Group specificity does not depend on whether the enzyme uses cofactors.

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

All of the following characteristics enhance the survival of encapsulated pathogenic bacteria E...

CORE CONCEPT & DERIVATION

The bacterial capsule is an extracellular polysaccharide or polypeptide layer that acts as a major virulence factor by masking surface antigens and preventing phagocytosis.

Formula / Rule / Reaction:

Qualitative concept / Bacteriology.

Solution:

- Capsules conceal underlying cell wall antigens such as lipopolysaccharides and peptidoglycan.
- This prevents recognition by pattern recognition receptors (e.g., Toll-like receptors) on host macrophages.
- Because capsules inhibit recognition and clearance, ease of recognition by the host is an incorrect characteristic.

Why other options are incorrect:

- Option A:** By blocking complement binding and phagocytosis, capsules significantly increase pathogenicity.
- Option B:** The hydrophilic polysaccharide matrix retains water, protecting bacteria from desiccation.
- Option C:** Capsular adhesins help bacteria attach firmly to host mucosal surfaces.

Question #17 Key: (B)BIOLOGY
08. Immunity

Probiotics in infant formula milk represent normal gut microflora. They benefit infants through...

CORE CONCEPT & DERIVATION

Probiotic bacteria (such as *Bifidobacterium* and *Lactobacillus*) improve host health through competitive exclusion, metabolic production, and immunomodulation. They do not possess eukaryotic phagocytic machinery.

Formula / Rule / Reaction:

Factual recall / Applied Microbiology.

Solution:

- Phagocytosis is an endocytic process performed exclusively by eukaryotic cells with cytoskeletons (such as macrophages and neutrophils).
- Prokaryotes are surrounded by a rigid peptidoglycan cell wall and cannot undergo endocytosis or phagocytosis.
- Probiotics inhibit pathogens by producing bacteriocins, organic acids, and competing for nutrients and adhesion sites.

Why other options are incorrect:

- Option A:** Enteric microflora synthesize vitamin K, biotin, folate, and other B-complex vitamins.
- Option C:** Probiotic colonization forms a physical barrier that prevents pathogen adherence to the intestinal epithelium.
- Option D:** Probiotics stimulate secretory IgA production and strengthen tight junctions between epithelial cells.

Question #18 Key: (C)BIOLOGY
06. Digestion/Nutrition

Activation of all of the following digestive enzymes requires a specific activator molecule EXC...

CORE CONCEPT & DERIVATION

Many proteases are secreted as inactive zymogens to prevent self-digestion of secretory cells and ducts. Erepsin refers to a mixture of active peptidase enzymes secreted by the intestinal mucosa.

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

- Erepsin (a complex of dipeptidases, aminopeptidases, and carboxypeptidases) is active upon secretion by the crypts of Lieberkuhn.
- Pepsinogen requires hydrochloric acid (HCl) or existing pepsin for cleavage of its inhibitory peptide.
- Trypsinogen requires enteropeptidase (enterokinase) for activation.
- Chymotrypsinogen requires active trypsin for proteolytic activation.

Why other options are incorrect:

- Option A:** Pepsinogen is an inactive zymogen that requires acid activation.
- Option B:** Trypsinogen is inactive until cleaved by duodenal enteropeptidase.
- Option D:** Chymotrypsinogen is an inactive zymogen dependent on trypsin.

Question #19 Key: (A)BIOLOGY
07. Circulation / Transport

Weakened or ruptured papillary muscles in the right ventricle will cause abnormal backflow of b...

CORE CONCEPT & DERIVATION

Papillary muscles in the ventricular walls contract during systole to pull on the chordae tendineae, preventing the atrioventricular valve cusps from everting into the atria.

Formula / Rule / Reaction:

Qualitative concept / Cardiovascular Anatomy.

Solution:

- The right ventricle contains the tricuspid valve tethered by chordae tendineae to right ventricular papillary muscles.
- During ventricular systole, high intraventricular pressure forces blood into the pulmonary artery while closing the tricuspid valve.
- Weakened papillary muscles allow tricuspid cusps to prolapse into the low-pressure right atrium.
- This produces tricuspid regurgitation, allowing blood to flow back into the right atrium.

Why other options are incorrect:

- Option B:** The left atrium receives regurgitant blood when the mitral (bicuspid) valve of the left ventricle fails.
- Option C:** Backflow into the left ventricle occurs across an incompetent aortic valve, not a right-sided valve.
- Option D:** Forward ejection into the pulmonary trunk is reduced, not characterized by backward flow.

Question #20 Key: (B)BIOLOGY
06. Digestion/Nutrition

A patient who has undergone cholecystectomy experiences difficulty in digesting large fatty mea...

CORE CONCEPT & DERIVATION

The gallbladder does not synthesize bile; it stores, acidifies, and concentrates bile secreted by hepatocytes, discharging a concentrated bolus in response to cholecystokinin (CCK) during a fatty meal.

Formula / Rule / Reaction:

Qualitative concept / Digestive Physiology.

Solution:

- Following cholecystectomy (gallbladder removal), hepatocytes continue to produce bile.
- Without a storage reservoir, bile drips slowly and continuously through the common bile duct into the duodenum.
- When a large fatty meal enters the intestine, the dilute bile supply is insufficient to quickly emulsify large fat globules.

Why other options are incorrect:

- Option A:** Hepatocytes in the liver synthesize bile acids continuously, regardless of gallbladder presence.
- Option C:** Pancreatic lipase is synthesized and secreted by the acinar cells of the pancreas, unaffected by gallbladder removal.
- Option D:** Bile pigments (bilirubin/biliverdin) are present in the continuous bile flow and do not participate in fat emulsification.

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

The peroxisomal enzyme catalase protects plant cells from the toxic accumulation of:

CORE CONCEPT & DERIVATION

Catalase is an antioxidant enzyme localized within peroxisomes that catalyzes the rapid dismutation of cytotoxic hydrogen peroxide (H_2O_2) into water and molecular oxygen.

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

- During photorespiration in C_3 plants, glycolate moves from chloroplasts into peroxisomes.
- Glycolate oxidase oxidizes glycolate to glyoxylate, producing toxic hydrogen peroxide (H_2O_2).
- Catalase quickly degrades H_2O_2 to prevent oxidative damage to membrane lipids, DNA, and enzymes.

Why other options are incorrect:

- **Option A:** Nitrogen gas is unreactive under physiological conditions and does not require catalase detoxification.
- **Option B:** Glucose-6-phosphate is a normal metabolic intermediate processed in glycolysis and the pentose phosphate pathway.
- **Option D:** Cellulose is a structural polysaccharide synthesized at the plasma membrane by cellulose synthase complexes.

Question #22 Key: (A)BIOLOGY
07. Circulation / Transport

Which set of anatomical characteristics correctly describes veins?

CORE CONCEPT & DERIVATION

Veins are low-pressure capacitance vessels that return deoxygenated blood to the heart. They have thinner muscular walls, larger compliant lumens, and semilunar valves to prevent backward flow.

Formula / Rule / Reaction:

Qualitative concept / Vascular Histology.

Solution:

- Veins operate under low hydrostatic pressure ($< 15 \text{ mmHg}$) compared to arteries.
- Their tunica media contains less smooth muscle and elastic tissue, resulting in thinner walls and wider lumens.
- Folds of the tunica intima form semilunar valves, particularly in the limbs, preventing backflow of blood.

Why other options are incorrect:

- **Option B:** Thick muscular walls and narrow lumens are histological hallmarks of high-pressure arteries.
- **Option C:** A single endothelial layer without smooth muscle describes capillaries, not veins.
- **Option D:** Systemic veins rely on valves to facilitate venous return against gravity.

Question #23 Key: (B)BIOLOGY
07. Circulation / Transport

Which physiological parameter would remain UNCOMPROMISED in a patient following complete disrup...

CORE CONCEPT & DERIVATION

The lymphatic system maintains tissue fluid homeostasis, absorbs dietary lipids from the gut, and facilitates adaptive immune surveillance. Oxygen transport is handled by hemoglobin within erythrocytes in the cardiovascular system.

Formula / Rule / Reaction:

$$\text{Total O}_2 \text{ Content} = (1.34 \times [\text{Hb}] \times S_{\text{O}_2}) + (0.003 \times P_{\text{O}_2})$$

Solution:

- Oxygen-carrying capacity depends on erythrocyte count, functional hemoglobin concentration, and alveolar gas exchange.
- Erythrocytes remain entirely within the closed blood vasculature and do not circulate through lymphatics.
- Lymphatic disruption causes severe lymphedema, impaired lipid uptake, and immunodeficiency, but does not alter hemoglobin oxygen-binding capacity.

Why other options are incorrect:

- **Option A:** The lymphatic system returns filtered interstitial fluid to the blood; its absence leads directly to tissue edema.
- **Option C:** Chylomicrons enter intestinal lacteals; blocking lymphatics halts systemic fat absorption.
- **Option D:** Dendritic cells travel via afferent lymphatics to present antigens to T cells in lymph nodes.

Question #24 Key: (D)BIOLOGY
07. Circulation / Transport

The presence of which components primarily distinguishes circulating whole blood from interstiti...

CORE CONCEPT & DERIVATION

Capillary walls function as semi-permeable membranes that allow water, gases, and small crystalloids to filter into the interstitial space while retaining cellular elements and large colloidal proteins.

Formula / Rule / Reaction:

$$\text{Net Filtration Pressure} = (P_c - P_{if}) - (\pi_c - \pi_{if})$$

Solution:

- Continuous capillary walls hold back cellular components (erythrocytes, leukocytes, and platelets).
- They are also largely impermeable to large plasma proteins (albumin, globulins, and fibrinogen).
- Interstitial fluid is an ultrafiltrate of blood plasma, containing small ions and glucose while lacking red blood cells and large proteins.

Why other options are incorrect:

- **Option A:** Glucose and Na^+ freely cross capillary fenestrations and are found in both fluids.
- **Option B:** Amino acids and chloride ions diffuse rapidly down concentration gradients into the interstitium.
- **Option C:** Small molecules like bicarbonate and urea equilibrate across capillary walls.

Question #25 Key: (C)BIOLOGY
07. Circulation / Transport

Mesophytic plants placed in highly saline soils face physiological drought because:

CORE CONCEPT & DERIVATION

Water moves passively down a water potential gradient, flowing from regions of higher (less negative) ψ_w to regions of lower (more negative) ψ_w .

Formula / Rule / Reaction:

$$\psi_w = \psi_s + \psi_p$$

$$\Delta\psi_w = \psi_{w, \text{root}} - \psi_{w, \text{soil}} > 0 \implies \text{Exosmosis occurs}$$

Solution:

- Excessive dissolved salts in saline soil lower the solute potential (ψ_s), making the soil water potential ($\psi_{w, \text{soil}}$) extremely negative.
- When $\psi_{w, \text{root}} > \psi_{w, \text{soil}}$, water moves out of the root cells into the hypertonic soil via exosmosis.
- The plant loses turgor and wilts, experiencing physiological drought despite the presence of liquid water in the soil.

Why other options are incorrect:

- Option A:** If soil water potential were higher than root water potential, water would enter the plant by endosmosis.
- Option B:** Aquaporins in root cell membranes remain permeable to water.
- Option D:** High salt concentrations increase soil osmotic pressure; they do not cause it to drop to zero.

Question #26 Key: (A)BIOLOGY
08. Immunity

During the COVID-19 pandemic, the administration of convalescent plasma from recovered patients...

CORE CONCEPT & DERIVATION

Convalescent plasma therapy provides artificial passive immunity by transferring preformed polyclonal antibodies from a recovered individual to an infected recipient.

Formula / Rule / Reaction:

Neutralization: Antibody (IgG) + Viral Spike Epitope $\longrightarrow$ Immune Complex (Inactivation)

Solution:

- Individuals who recover from viral infections develop high titers of specific neutralizing antibodies (mainly IgG).
- Transfusing their plasma into sick patients transfers these preformed antibodies.
- These donor antibodies bind viral surface antigens (e.g., spike proteins), neutralizing virions and promoting phagocytosis before the recipient's immune system mounts its own response.

Why other options are incorrect:

- Option B:** Interleukin-1 is a pro-inflammatory cytokine that can worsen systemic cytokine storms.
- Option C:** Plasminogen is an inactive fibrinolytic precursor involved in dissolving blood clots, not viral immunity.
- Option D:** Pancreatic digestive enzymes are absent from therapeutic plasma.

Question #27 Key: (C)BIOLOGY
08. Immunity

Which of the following scenarios represents an example of artificial active immunity?

CORE CONCEPT & DERIVATION

Active immunity occurs when the host's own immune system produces antibodies and memory cells in response to an antigen. It is artificial when the antigen is administered intentionally via medical vaccination.

Formula / Rule / Reaction:

Factual recall / Immunology.

Solution:

- Vaccination with MMR introduces attenuated live viral antigens into the infant.
- The infant's immune system processes these antigens, producing specific antibodies and long-lived memory B and T cells.
- Because antigen exposure was induced medically, this represents artificial active immunity.

Why other options are incorrect:

- Option A:** Transplacental transfer of maternal IgG provides natural passive immunity.
- Option B:** Injecting preformed anti-tetanus immunoglobulins provides artificial passive immunity.
- Option D:** Recovering from a natural chickenpox infection produces natural active immunity.

Question #28 Key: (A)BIOLOGY
08. Immunity

Which specific subset of T lymphocytes is required for the activation, clonal expansion, and an...

CORE CONCEPT & DERIVATION

T-dependent B cell activation requires physical engagement and cytokine signals provided by antigen-primed CD4⁺ helper T cells.

Formula / Rule / Reaction:

TCR – MHC-II + CD40 – CD40L + Cytokines (IL-4, IL-5, IL-21) $\longrightarrow$ B-cell Clonal Expansion

Solution:

- B cells present peptide antigens on class II MHC surface molecules.
- Helper T cells (CD4⁺ T_H) recognize this peptide-MHC-II complex via their T-cell receptors (TCR).
- The helper T cell engages CD40 on the B cell via CD40 ligand (CD40L) and secretes cytokines (IL-4, IL-5, IL-21).
- These signals induce B-cell proliferation, somatic hypermutation, affinity maturation, and class switching into plasma cells.

Why other options are incorrect:

- Option B:** Cytotoxic CD8⁺ T cells recognize MHC-I and kill virally infected or neoplastic cells via perforins and granzymes.
- Option C:** Regulatory T cells downregulate immune responses to maintain self-tolerance.
- Option D:** Natural killer cells participate in innate immunity and do not direct B-cell class switching.

Question #29 Key: (D)BIOLOGY
12. Nervous Coordination

What is the normal physiological fate of neurotransmitter molecules after transmitting an action potential?

CORE CONCEPT & DERIVATION

Synaptic transmission requires rapid termination to ensure that subsequent action potentials are transmitted as distinct, discrete signals.

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

- Once a neurotransmitter dissociates from its postsynaptic receptor, it must be cleared quickly.
- Clearance occurs through enzymatic degradation (e.g., acetylcholinesterase cleaving ACh), reuptake into the presynaptic terminal via secondary active transporters, or diffusion away into surrounding glial cells.
- This rapid removal repolarizes the postsynaptic membrane, readying it for the next signal.

Why other options are incorrect:

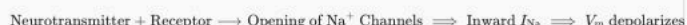
- Option A:** Permanent binding would lead to desensitization and excitotoxic damage.
- Option B:** Neurotransmitters are signaling ligands; they are not transported into the postsynaptic soma as metabolic fuel.
- Option C:** Uncontrolled accumulation in the cleft would cause tetanic stimulation and block further signaling.

Question #30 Key: (B)BIOLOGY
12. Nervous Coordination

Which immediate event occurs at the postsynaptic membrane when an excitatory neurotransmitter binds?

CORE CONCEPT & DERIVATION

Excitatory neurotransmitters bind to ligand-gated ion channels, increasing membrane permeability to cations (primarily Na^+) and producing an excitatory postsynaptic potential (EPSP).

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

- Binding of excitatory neurotransmitters (e.g., acetylcholine or glutamate) opens ligand-gated cation channels.
- Sodium ions (Na^+) rush into the postsynaptic neuron along both concentration and electrical gradients.
- This influx of positive charge depolarizes the local membrane toward threshold, generating an EPSP.

Why other options are incorrect:

- Option A:** Voltage-gated Ca^{2+} channel opening occurs at the presynaptic terminal to trigger vesicle fusion, not on the postsynaptic membrane.
- Option C:** Na^+/K^+ pumps continue running to maintain steady-state ion gradients.
- Option D:** Opening chloride (Cl^-) channels causes hyperpolarization, generating an inhibitory postsynaptic potential (IPSP).

Question #31 Key: (B)BIOLOGY
12. Nervous Coordination

During the propagation of an action potential along a neuronal axon, hyperpolarization (the undershoot) occurs because:

CORE CONCEPT & DERIVATION

Hyperpolarization occurs because voltage-gated K^+ channels close slowly, allowing continued potassium efflux that drives the membrane potential toward the potassium equilibrium potential ($\approx -90 \text{ mV}$).

Formula / Rule / Reaction:

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

Solution:

- During repolarization, voltage-gated K^+ channels open to allow K^+ efflux, restoring internal negativity.
- Because these gates close with a slight delay, K^+ continues to leave the cell even after reaching the resting potential (-70 mV).
- This extra efflux temporarily drives the potential down toward E_K (hyperpolarization).
- If these channels closed instantly upon reaching -70 mV , hyperpolarization would not occur.

Why other options are incorrect:

- Option A:** Failure of sodium channels to inactivate would prolong depolarization, preventing repolarization altogether.
- Option C:** The Na^+/K^+ pump restores baseline ion distributions over time, but is not responsible for the immediate hyperpolarization phase.
- Option D:** Calcium influences neurotransmitter release and membrane excitability threshold, but does not drive axonal undershoot.

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

Which of the following is a characteristic feature of an electrical synapse?

CORE CONCEPT & DERIVATION

Electrical synapses allow direct electrical coupling between adjacent cells through connexon-formed gap junctions, providing near-instantaneous bidirectional current flow without neurotransmitters.

Formula / Rule / Reaction:

Qualitative concept / Neurobiology.

Solution:

- In electrical synapses, presynaptic and postsynaptic membranes lie close together (≈ 2 to 4 nm).
- Intercellular gap junctions formed by hexameric connexin hemichannels connect the two cytoplasm directly.
- Ions pass through these channels via electrotonic conduction with virtually zero synaptic delay ($< 0.1 \text{ ms}$).

Why other options are incorrect:

- Option A:** A 20 to 40 nm synaptic cleft is characteristic of chemical synapses.
- Option B:** Neurotransmitter synthesis, storage, and exocytosis occur exclusively at chemical synapses.
- Option C:** Synaptic delay is typical of chemical synapses, whereas electrical synapses provide nearly instantaneous transmission.

Question #33 Key: (C)BIOLOGY
12. Nervous Coordination

Which statement correctly characterizes the absolute refractory period of an excitable neuronal...

CORE CONCEPT & DERIVATION

The absolute refractory period is the interval following an action potential during which the axon is completely incapable of generating another spike, ensuring unidirectional signal propagation.

Formula / Rule / Reaction:

Factual recall / Electrophysiology.

Solution:

- During the upstroke and early repolarization, voltage-gated Na^+ channels become inactivated by their intracellular inactivation gates (ball-and-chain mechanism).
- Inactivated Na^+ channels cannot reopen until the membrane repolarizes to near resting potential.
- Because an inward sodium current cannot be triggered during this time, no stimulus can initiate another action potential.

Why other options are incorrect:

- **Option A:** Eliciting a spike with a suprathreshold stimulus describes the relative refractory period, when sodium channels have reset but potassium conductance remains high.
- **Option B:** Neuronal membrane potentials never drop to -150 mV ; the lower limit is set by E_K around -90 mV .
- **Option D:** Inactivation gates are closed during this period, blocking the channel pore.

Question #34 Key: (A)BIOLOGY
12. Nervous Coordination

During the complex motor activity of flight, birds must coordinate many skeletal muscles simult...

CORE CONCEPT & DERIVATION

The cerebellum integrates sensory input from the vestibular apparatus, eyes, and proprioceptors to coordinate voluntary muscle movements, maintain equilibrium, and regulate postural tone.

Formula / Rule / Reaction:

Qualitative concept / Neuroanatomy.

Solution:

- Avian flight requires precise real-time adjustments of wing, tail, and body musculature across three dimensions.
- The cerebellum processes proprioceptive and balance signals to coordinate fine motor control and maintain equilibrium.
- Consequently, birds have an enlarged, highly developed cerebellum relative to their overall brain size.

Why other options are incorrect:

- **Option B:** The cerebrum handles sensory perception, learning, and voluntary motor initiation, but not fine cerebellar coordination.
- **Option C:** The amygdala is a limbic nucleus involved in emotional processing and fear conditioning.
- **Option D:** The hypothalamus regulates autonomic functions, body temperature, and endocrine homeostasis.

Question #35 Key: (B)BIOLOGY
12. Nervous Coordination

Which part of the human brain is most actively used by a mathematician when working through an...

CORE CONCEPT & DERIVATION

Higher-order cognitive functions such as abstract reasoning, mathematical analysis, and logical deduction are localized in the cerebral cortex, especially within the frontal and parietal association areas.

Formula / Rule / Reaction:

Qualitative concept / Neuroanatomy.

Solution:

- The cerebrum (specifically the prefrontal cortex and parietal association areas) handles analytical reasoning.
- Formulating and solving novel equations requires working memory, symbol manipulation, and abstract logic.
- These intellectual processes depend on coordinated activity across cerebral cortical networks.

Why other options are incorrect:

- **Option A:** The medulla oblongata controls vital autonomic reflexes like breathing, heart rate, and vasomotor tone.
- **Option C:** The amygdala processes emotions, fear conditioning, and emotional memory consolidation.
- **Option D:** The pons serves as a bridge relaying signals between the cerebrum, cerebellum, and respiratory rhythm centers.

Question #36 Key: (B)BIOLOGY
10. Homeostasis

A mammal stranded in an arid desert faces severe dehydration. Which internal condition directly...

CORE CONCEPT & DERIVATION

Antidiuretic hormone (vasopressin) is secreted in response to cellular dehydration. Hypothalamic osmoreceptors detect elevated extracellular fluid osmolarity and stimulate ADH release.

Formula / Rule / Reaction:

$\uparrow$ Plasma Osmolarity $\Rightarrow$ Osmoreceptor Shrinkage $\Rightarrow$ $\uparrow$ ADH Release from Neurohypophysis

Solution:

- Dehydration reduces free water volume, concentrating solutes (e.g., Na^+) in the plasma and raising its osmotic pressure.
- Central osmoreceptors in the anterior hypothalamus lose water by osmosis and shrink.
- This mechanical deformation generates action potentials that trigger ADH release from the posterior pituitary.
- ADH acts on kidney collecting ducts to insert aquaporin-2 channels, promoting water reabsorption and concentrating the urine.

Why other options are incorrect:

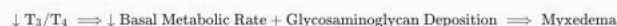
- **Option A:** Decreased osmolarity indicates overhydration, which inhibits ADH secretion to promote water excretion.
- **Option C:** High blood pressure stretches baroreceptors, sending signals that suppress ADH secretion.
- **Option D:** Ingestion of hypotonic water dilutes plasma solutes, turning off osmoreceptor stimulation.

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

Which endocrine disorder is diagnosed in an adult patient presenting with thick, dry, and coars...

CORE CONCEPT & DERIVATION

Severe, chronic hypothyroidism in adult patients leads to a generalized slowing of metabolic processes, accompanied by the accumulation of hydrophilic glycosaminoglycans in connective tissues.

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

- Deficiency of thyroid hormones (T_3 and T_4) lowers cellular metabolic activity, causing cold intolerance and weight gain.
- Subcutaneous accumulation of mucopolysaccharides (hyaluronic acid and chondroitin sulfate) traps water, producing non-pitting edema (myxedema).
- This causes facial swelling, swollen eyelids (periorbital puffiness), and coarse, dry skin.

Why other options are incorrect:

- Option A:** Cretinism is congenital hypothyroidism in infants, characterized by severe growth stunting and intellectual disability.
- Option B:** Cushing syndrome results from hypercortisolemia and features a rounded moon face, purple striae, and hypertension.
- Option D:** Addison disease is primary adrenal insufficiency, causing skin hyperpigmentation, fatigue, and hypotension.

Question #38 Key: (C)BIOLOGY
13. Chemical Coordination

Which of the following clinical conditions is directly associated with hypoparathyroidism?

CORE CONCEPT & DERIVATION

Parathyroid hormone (PTH) maintains extracellular calcium levels by stimulating bone resorption, renal calcium reabsorption, and activation of vitamin D. A deficiency in PTH causes blood calcium levels to drop (hypocalcemia).

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

- Hypoparathyroidism decreases parathyroid hormone secretion, leading to hypocalcemia and hyperphosphatemia.
- Low extracellular Ca^{2+} lowers the threshold of voltage-gated Na^+ channels, making neurons hyperexcitable.
- Spontaneous repetitive firing of motor axons triggers painful, sustained muscle spasms known as tetany (e.g., carpopedal spasm).

Why other options are incorrect:

- Option A:** Nephrolithiasis (kidney stones) and osteopenia result from hyperparathyroidism, which elevates blood calcium.
- Option B:** Hypoparathyroidism causes hypocalcemia, not hypercalcemia.
- Option D:** Hypercalcemia decreases neuronal excitability and causes muscle flaccidity; hypocalcemia produces spasms and tetany.

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

Choose the **MISMATCHED** endocrine pair regarding reproductive physiology:

CORE CONCEPT & DERIVATION

The ovarian cycle is regulated by gonadotropins and ovarian steroids. Maturing Graafian follicles secrete primarily estrogens; progesterone is secreted in large amounts only after ovulation by the corpus luteum.

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

- The maturing Graafian follicle consists of theca and granulosa cells that convert androgens to estrogens.
- Progesterone is synthesized in large quantities by the corpus luteum, which develops from the collapsed follicle following ovulation.
- Therefore, attributing primary progesterone secretion to the pre-ovulatory Graafian follicle is incorrect.

Why other options are incorrect:

- Option B:** ICSH (the male equivalent of luteinizing hormone) targets Leydig interstitial cells in the testes to synthesize testosterone.
- Option C:** Moderate levels of estrogen exert negative feedback on the anterior pituitary to suppress FSH release during the follicular phase.
- Option D:** A mid-cycle surge of LH triggers follicular rupture, primary oocyte maturation completion, and ovulation.

Question #40 Key: (D)BIOLOGY
13. Chemical Coordination

Which of the following physiological processes is governed by a negative feedback mechanism?

CORE CONCEPT & DERIVATION

Negative feedback loops maintain physiological homeostasis by detecting deviations from a predetermined set point and triggering effector responses that counteract the original disturbance.

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

- When core temperature rises, hypothalamic thermoreceptors trigger cutaneous vasodilation and sweating to promote heat loss.
- When core temperature falls, vasoconstriction, non-shivering thermogenesis, and shivering generate and conserve heat.
- Both responses counteract the initial temperature deviation, maintaining homeostasis via negative feedback.

Why other options are incorrect:

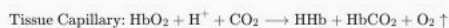
- Option A:** Activated platelets release thromboxane A_2 and ADP, which recruit and activate more platelets in a self-amplifying positive feedback cascade.
- Option B:** Uterine contractions force the fetal head against the cervix, stimulating cervical stretch receptors that trigger more oxytocin release in a positive feedback loop (Ferguson reflex).
- Option C:** Infant suckling stimulates continuous tactile receptors, sending signals to the posterior pituitary to release more oxytocin in a positive feedback loop.

Question #41 Key: (C)BIOLOGY
09. Respiration / Gaseous Exchange

Most carbon dioxide is transported through the bloodstream as bicarbonate ions. Which of the fo...

CORE CONCEPT & DERIVATION

At systemic tissues, low oxygen partial pressure and high metabolic carbon dioxide promote oxygen unloading from hemoglobin (Bohr effect) and the formation of bicarbonate inside erythrocytes.

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

- At the tissues, oxyhemoglobin dissociates to release free oxygen into the interstitium, generating deoxyhemoglobin.
- Carbonic anhydrase converts CO_2 to carbonic acid, which dissociates into H^+ and HCO_3^- .
- Deoxyhemoglobin buffers H^+ to form reduced hemoglobin (HHb), while bicarbonate is exchanged for chloride (chloride shift).
- Oxyhemoglobin formation occurs exclusively in pulmonary capillaries, not at systemic tissue level.

Why other options are incorrect:

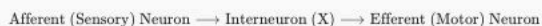
- Option A:** Deoxyhemoglobin serves as a terminal proton buffer at the tissue level, binding free H^+ to form HHb.
- Option B:** Bicarbonate ions entering the plasma associate with sodium ions to form transportable sodium bicarbonate.
- Option D:** An inward chloride shift (Hamburger phenomenon) occurs at the tissues to maintain electrical neutrality as HCO_3^- leaves erythrocytes.

Question #42 Key: (B)BIOLOGY
12. Nervous Coordination

The diagram below illustrates a spinal reflex arc with a neural component labeled X: Sensory Ne...

CORE CONCEPT & DERIVATION

Interneurons (relay/association neurons) reside entirely within the central nervous system grey matter, processing and transmitting signals between sensory afferents and motor efferents, or up ascending tracts toward higher brain centers.

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

- Interneurons receive incoming synaptic inputs from primary sensory neuron axons in the dorsal horn.
- They integrate these inputs and synapse with alpha motor neurons in the ventral horn or send collateral axons into white matter tracts toward the brain.
- Interneurons are multipolar cells restricted to the CNS and do not project retrogradely into peripheral sensory receptor organs.

Why other options are incorrect:

- Option A:** Polysynaptic spinal interneurons send collateral axons up spinothalamic tracts to conscious brain centers.
- Option C:** Sensory axons entering the dorsal root enter the dorsal horn and form excitatory synapses with interneuron dendrites.
- Option D:** Interneuron cell bodies and their synaptic connections are contained within the spinal central grey matter.

Question #43 Key: (C)BIOLOGY
01. Cell

Which of the following functions is directly mediated by integral plasma membrane proteins?

CORE CONCEPT & DERIVATION

Integral membrane proteins span the lipid bilayer and function as selective channels, carrier proteins, and ATP-dependent pumps that mediate the transmembrane movement of charged or polar species.

Formula / Rule / Reaction:

$$\text{Flux } J = -P \cdot A \cdot (C_{\text{in}} - C_{\text{out}}) \quad \text{or active transport via Na}^+/\text{K}^+ \text{-ATPase}$$

Solution:

- The hydrophobic core of the phospholipid bilayer is impermeable to inorganic ions (e.g., Na^+ , K^+ , Ca^{2+} , Cl^-).
- Transmembrane protein channels (e.g., voltage-gated ion channels) and transport ATPases provide hydrophilic conduits for ion transport.
- This facilitated transport and active pumping is a primary biological function of membrane proteins.

Why other options are incorrect:

- Option A:** Non-polar gases (O_2 , CO_2 , N_2) dissolve directly in the lipid matrix and diffuse across without protein mediation.
- Option B:** Cold adaptation and phase flexibility are mediated by unsaturated fatty acid tails and cholesterol molecules.
- Option D:** The continuous fluid matrix is formed by amphipathic phospholipid bilayers, not proteins.

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

When grasped by a predator, a lizard can deliberately sever its own tail to escape. This physio...

CORE CONCEPT & DERIVATION

Autotomy is the self-amputation of a non-vital body appendage along preformed fracture planes, used as an antipredator evasion reflex in several invertebrate and vertebrate taxa.

Formula / Rule / Reaction:

Factual recall / Animal Behavior.

Solution:

- Caudal autotomy allows lizards to cast off their tail via reflex muscular contraction through specialized vertebral fracture planes.
- The wriggling severed tail distracts the predator, allowing the animal to escape.
- Regeneration of a cartilaginous rod and replacement tissue follows over subsequent weeks.

Why other options are incorrect:

- Option A:** Autophagy is a lysosomal catabolic pathway by which a single cell degrades its own damaged organelles or misfolded proteins.
- Option C:** Phagocytosis is the receptor-mediated endocytosis of large external particles by specialized cells.
- Option D:** Heterophagy is the lysosomal breakdown of exogenous materials internalized into a cell from the extracellular environment.

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

Which set of biophysical characteristics correctly describes eukaryotic intermediate filaments?

CORE CONCEPT & DERIVATION

Intermediate filaments are tough, rope-like cytoskeletal polymers with a diameter between microfilaments and microtubules that provide tensile strength to withstand mechanical stress.

Formula / Rule / Reaction:

Microfilaments ($\approx 7 \text{ nm}$) < Intermediate Filaments (8 to 10 nm) < Microtubules ($\approx 25 \text{ nm}$)

Solution:

- Intermediate filaments have an intermediate diameter measuring approximately 8 to 10 nm.
- They are assembled from fibrous subunit proteins including vimentin, keratins, neurofilaments, and nuclear lamins.
- Their primary physiological role is structural: providing mechanical support, maintaining cellular shape, and anchoring organelles like the nucleus.

Why other options are incorrect:

- Option B:** Tubulin dimers assemble into hollow cylinders of 25 nm diameter, which defines microtubules.
- Option C:** Actin polymers with a 7 nm diameter represent microfilaments, which drive cyclosis and cytokinesis.
- Option D:** Myosin forms thick filaments in striated muscle sarcomeres, which act as motor proteins rather than structural intermediate filaments.

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

Nucleoproteins play a primary physiological role in:

CORE CONCEPT & DERIVATION

Nucleoproteins are stable conjugated complexes formed by the association of nucleic acids (DNA or RNA) with specialized basic structural proteins (such as histones or protamines).

Formula / Rule / Reaction:

Chromatin Core: dsDNA (147 bp) + Histone Octamer (H2A, H2B, H3, H4)₂ $\rightarrow$ Nucleosome

Solution:

- In eukaryotic nuclei, genomic DNA is complexed with basic histone proteins to form chromatin.
- These nucleoprotein complexes compact DNA, protect double helices from physical breakage, and regulate gene expression.
- During cell division, chromosomes faithfully transmit this nucleoprotein-packaged genetic code to daughter cells.

Why other options are incorrect:

- Option A:** The glycocalyx is composed of glycoproteins and glycolipids projecting from the outer plasma membrane leaflet.
- Option C:** Saltatory nerve transmission depends on myelin sheath lipids and nodal voltage-gated sodium channels.
- Option D:** Triglyceride synthesis is carried out by enzymatic acyltransferases on smooth endoplasmic reticulum membranes.

Question #47 Key: (C)BIOLOGY
14. Reproduction

If the menstrual cycle of a healthy female begins with the onset of menses on the 10th of July,...

CORE CONCEPT & DERIVATION

In a standard 28-day human menstrual cycle, day 1 corresponds to the first day of menstrual bleeding. Ovulation consistently occurs 14 days prior to the subsequent menses (typically around day 14 of the cycle).

Formula / Rule / Reaction:

Day of Ovulation = Onset Date + 14 days

Solution:

- The cycle starts on Day 1, which corresponds to July 10th.
- In a 28-day cycle, the pre-ovulatory follicular phase lasts approximately 14 days.
- Adding 14 days to the onset date: July 10 + 14 = July 24.
- Therefore, the mid-cycle LH surge and subsequent ovulation occur on July 24th.

Why other options are incorrect:

- Option A:** August 1st represents day 23 of the cycle, corresponding to the mid-luteal secretory phase.
- Option B:** July 28th corresponds to day 19, which is well into the post-ovulatory luteal phase.
- Option D:** August 5th corresponds to day 27, just prior to the onset of the next menstrual bleed.

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

Which of the following cells is formed directly as a result of reduction division (meiosis I) d...

CORE CONCEPT & DERIVATION

Meiosis I is the true reduction division of gametogenesis, where homologous chromosome pairs segregate, reducing the chromosome number from diploid (2n) to haploid (n).

Formula / Rule / Reaction:

Primary Oocyte (2n, 4c) $\xrightarrow{\text{Meiosis I (Reductional)}}$ Secondary Oocyte (n, 2c) + First Polar Body (n, 2c)

Solution:

- Oogonia undergo mitotic amplification to produce diploid primary oocytes before birth.
- Primary oocytes arrest in prophase I until stimulated by gonadotropins at puberty.
- Completion of meiosis I just before ovulation yields a haploid secondary oocyte and a small first polar body.
- Thus, the secondary oocyte is the direct product of the first meiotic reduction division.

Why other options are incorrect:

- Option A:** Oogonia are diploid stem cells produced by mitotic proliferation of primordial germ cells.
- Option B:** Primary oocytes are formed by the differentiation and DNA replication of oogonia prior to meiotic division.
- Option C:** Primary spermatocytes are diploid cells derived mitotically from type B spermatogonia before meiotic division.

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

In garden peas, purple flower color (P) is dominant over white (p), and axial flower position (...)

CORE CONCEPT & DERIVATION

According to Mendel's Law of Independent Assortment, the phenotypic outcome of a dihybrid cross between heterozygous F_1 individuals follows a classic 9 : 3 : 3 : 1 phenotypic ratio.

Formula / Rule / Reaction:

$$\text{Parental: } PPAA \times ppaa \Rightarrow F_1 : PpAa$$

$$\text{Probability(Purple)} = \frac{3}{4}, \quad \text{Probability(Terminal)} = \frac{1}{4}$$

$$\text{Product Rule: } P(\text{Purple} \cap \text{Terminal}) = \frac{3}{4} \times \frac{1}{4} = \frac{3}{16}$$

Solution:

- The parental cross $PPAA \times ppaa$ yields uniform dihybrid F_1 plants with genotype $PpAa$.
- Self-fertilization of F_1 generates 16 genotypic combinations with a phenotypic ratio of 9 : 3 : 3 : 1.
- Phenotypes: 9/16 Purple Axial, 3/16 Purple Terminal, 3/16 White Axial, and 1/16 White Terminal.
- The fraction displaying the purple terminal recombinant phenotype is 3/16.

Why other options are incorrect:

- Option A:** 9/16 represents the probability of offspring displaying both dominant traits (purple axial).
- Option B:** 1/16 represents the probability of offspring displaying both recessive traits (white terminal).
- Option D:** 3/4 represents the monohybrid probability for flower color alone, ignoring flower position.

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

A woman who is a heterozygous carrier for hemophilia (an X-linked recessive disorder) marries a...

CORE CONCEPT & DERIVATION

Hemophilia A and B are X-linked recessive traits. Sons inherit their single X chromosome exclusively from their mother and their Y chromosome from their father, making maternal segregation the sole determinant of a son's phenotype.

Formula / Rule / Reaction:

$$\text{Mother: } X^H X^h, \quad \text{Father: } X^H Y$$

$$\text{Male Offspring Combinations: } \frac{1}{2} X^H Y \text{ (Normal)}, \quad \frac{1}{2} X^h Y \text{ (Affected)}$$

Solution:

- The mother carries one normal allele and one mutant allele ($X^H X^h$).
- The father contributes a Y chromosome to all male offspring.
- Each son has a 50% chance of inheriting the normal X^H allele and a 50% chance of inheriting the mutant X^h allele.
- Therefore, exactly 50% of their sons are predicted to be affected hemophiliacs.

Why other options are incorrect:

- Option A:** A 100% incidence in sons would require the mother to be homozygous affected ($X^h X^h$).
- Option C:** 25% is the overall fraction of affected individuals across all offspring of both sexes, not among sons specifically.
- Option D:** A 0% risk would only occur if the mother were homozygous normal ($X^H X^H$).

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

Which of the following statements is *INCORRECT* regarding the human ABO blood group system?

CORE CONCEPT & DERIVATION

The ABO blood group system on chromosome 9 codes for glycosyltransferase enzymes that attach specific terminal carbohydrate antigens (A or B) to the core H-antigen on the erythrocyte membrane.

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

- The ABO system is controlled by three alleles: I^A , I^B , and i .
- I^A and I^B encode functional enzymes that add specific sugars, creating A and B surface antigens.
- The null allele i produces an inactive protein, leaving the unmodified precursor H-substance.
- Stating that the system does not code for any antigen is factually incorrect.

Why other options are incorrect:

- Option A:** The presence of three distinct alleles (I^A , I^B , i) in the human population makes this a classic multiple-allele locus.
- Option B:** In an $I^A I^B$ individual, both transferases are active, leading to equal expression of both A and B antigens (codominance).
- Option D:** Individual alleles segregate during meiosis following Mendel's Law of Segregation.

Question #52 Key: (B)BIOLOGY
15. Inheritance / Variation & Genetics

Which of the following genetic statements correctly describes androgenic alopecia (pattern bald)...

CORE CONCEPT & DERIVATION

Sex-influenced traits are determined by autosomal genes whose phenotypic dominance is altered by the individual's sex hormones (specifically dihydrotestosterone).

Formula / Rule / Reaction:

Genotype Bb : Bald in males (dominant under high DHT), Non-bald in females

Solution:

- Pattern baldness is governed by an autosomal allele located on chromosome 4, not on the X or Y sex chromosomes.
- The baldness allele (B) behaves as dominant in males due to high circulating levels of testosterone and 5α -reductase.
- In females, low androgen levels cause the allele to behave as recessive, typically producing only diffuse thinning in homozygous individuals.

Why other options are incorrect:

- **Option A:** True pattern baldness is an autosomal sex-influenced trait, not an X-linked condition.
- **Option C:** Heterozygous males (Bb) develop pattern baldness because the allele is dominant in the male hormonal environment.
- **Option D:** Homozygous females (bb) experience mild crown thinning rather than the severe vertex balding seen in males.

Question #53 Key: (C)BIOLOGY
11. Support & Movement

Athletes frequently suffer hamstring strains. Which anatomical statement correctly describes th...

CORE CONCEPT & DERIVATION

The hamstring muscle group occupies the posterior compartment of the thigh and consists of the biceps femoris, semitendinosus, and semimembranosus. They span two joints, acting to extend the hip and flex the knee.

Formula / Rule / Reaction:

Factual recall / Musculoskeletal Anatomy.

Solution:

- The long head of the biceps femoris, semitendinosus, and semimembranosus share a common origin at the ischial tuberosity of the pelvic girdle.
- The short head of the biceps femoris originates from the linea aspera and lateral supracondylar line of the posterior femur.
- They cross the knee joint to insert on the proximal tibia and head of the fibula.

Why other options are incorrect:

- **Option A:** Hamstrings act as flexors of the knee joint and extensors of the hip joint.
- **Option B:** Insertion onto the patella and tibial tuberosity is performed by the quadriceps femoris extensor group.
- **Option D:** The anterior superior iliac spine serves as the origin for the sartorius and tensor fasciae latae, not the hamstrings.

Question #54 Key: (B)BIOLOGY
11. Support & Movement

Which of the following structural features characterizes a skeletal muscle sarcomere in its ful...

CORE CONCEPT & DERIVATION

According to the sliding filament theory of muscle contraction, thin actin filaments slide past thick myosin filaments toward the M-line during contraction, narrowing the H-zone and I-bands.

Formula / Rule / Reaction:

Relaxation: $[Ca^{2+}]_{cytosol} < 10^{-7} M \Rightarrow$ Tropomyosin blocks actin $\Rightarrow$ Broad H-zone

Solution:

- In resting muscle, calcium is actively sequestered inside the sarcoplasmic reticulum by SERCA pumps.
- Troponin-tropomyosin complexes block the myosin-binding sites on actin, preventing cross-bridge formation.
- Because actin filaments are drawn back away from the center of the sarcomere, the H-zone remains broad and distinct.

Why other options are incorrect:

- **Option A:** Myosin-binding sites on actin are physically blocked by tropomyosin during relaxation.
- **Option C:** Cross-bridge formation occurs exclusively during contraction in the presence of calcium and ATP.
- **Option D:** In relaxed muscle, cytoplasmic calcium is very low, while resting calcium is stored in the sarcoplasmic reticulum.

Question #55 Key: (C)BIOLOGY
16. Evolution

The children of a laborer do not inherit the hypertrophied skeletal muscles developed by their ...

CORE CONCEPT & DERIVATION

August Weismann's germplasm theory established that somatic cell modifications acquired during an individual's lifetime do not alter the genome of germ cells and cannot be passed to offspring.

Formula / Rule / Reaction:

Somatic Modification $\nrightarrow$ Germline DNA Sequence $\Rightarrow$ No Hereditary Transmission

Solution:

- Muscle hypertrophy from manual labor is an acquired somatic adaptation resulting from increased protein synthesis in muscle fibers.
- These somatic changes do not modify the genetic sequences contained within spermatogonia or spermatozoa.
- Because only germline mutations can be inherited, acquired somatic traits are not passed to subsequent generations.

Why other options are incorrect:

- **Option A:** Natural selection acts on heritable genetic variation, not on the direct non-transmission of somatic adaptations.
- **Option B:** Overproduction of offspring relates to demographic population dynamics and competitive survival.
- **Option D:** Lamarck proposed that acquired traits were inherited; the observation directly refutes this idea.

Question #56 Key: (C)

CHEMISTRY
01. StoichiometryCalcium reacts with sulfur according to the balanced equation: $\text{Ca(s)} + \text{S(s)} \rightarrow \text{CaS(s)}$...

CORE CONCEPT & DERIVATION

The yield of a chemical reaction is governed by the limiting reactant, which is the reagent present in the smallest stoichiometric amount relative to the balanced equation.

Formula / Rule / Reaction:

$$n = \frac{m}{M}, \quad m_{\text{product}} = n_{\text{limiting}} \times M_{\text{product}}$$

Solution:

- Calculate moles of available reactants:

$$n_{\text{Ca}} = \frac{2.0 \text{ g}}{40.08 \text{ g/mol}} \approx 0.0499 \text{ mol}$$

$$n_{\text{S}} = \frac{4.0 \text{ g}}{32.06 \text{ g/mol}} \approx 0.1248 \text{ mol}$$

- According to the 1 : 1 stoichiometry, 0.0499 mol of Ca requires 0.0499 mol of S.
- Sulfur is present in excess, making calcium the limiting reactant.
- Calculate the mass of CaS produced:

$$m_{\text{CaS}} = 0.0499 \text{ mol} \times 72.14 \text{ g/mol} \approx 3.60 \text{ g}$$

Why other options are incorrect:

- Option A:** 4.6 g incorrectly assumes sulfur is limiting or miscalculates the stoichiometric ratio.
- Option B:** 2.6 g underestimates the molar mass of the product.
- Option D:** 5.3 g would require calcium to be present in excess, which is chemically incorrect.

Question #57 Key: (B)

CHEMISTRY
01. Stoichiometry

Which of the following gaseous or elemental samples contains the greatest total number of molecules...

CORE CONCEPT & DERIVATION

The number of particles in a given mass is directly proportional to the number of moles, which is inversely proportional to the molar mass of the substance.

Formula / Rule / Reaction:

$$N = n \times N_A = \left(\frac{m}{M}\right) \times N_A$$

Solution:

- Calculate moles for each sample:

$$n_{\text{Na}} = \frac{2.0}{23} \approx 0.087 \text{ mol}$$

$$n_{\text{H}_2} = \frac{2.0}{2.0} = 1.000 \text{ mol}$$

$$n_{\text{N}_2} = \frac{2.0}{28} \approx 0.071 \text{ mol}$$

$$n_{\text{CO}_2} = \frac{2.0}{44} \approx 0.045 \text{ mol}$$

- Hydrogen gas has the smallest molar mass, yielding the largest number of moles (1.0 mol).
- Therefore, 2.0 g of H₂ contains the greatest number of particles (6.022×10^{23} molecules).

Why other options are incorrect:

- Option A:** 2 g of Na represents only 0.087 mol (approximately 5.2×10^{22} atoms).
- Option C:** 2 g of N₂ represents 0.071 mol (approximately 4.3×10^{22} molecules).
- Option D:** 2 g of CO₂ represents 0.045 mol (approximately 2.7×10^{22} molecules).

Question #58 Key: (B)

CHEMISTRY
02. Atomic StructureThe value of the azimuthal quantum number (l) for an electron residing in a $4p$ orbital is...

CORE CONCEPT & DERIVATION

The azimuthal quantum number (l) defines the orbital angular momentum and three-dimensional shape of an electron subshell, with values ranging from 0 to $n - 1$.

Formula / Rule / Reaction:

$$s \Rightarrow l = 0, \quad p \Rightarrow l = 1, \quad d \Rightarrow l = 2, \quad f \Rightarrow l = 3$$

Solution:

- In the designation $4p$, the principal quantum number is $n = 4$.
- The letter p designates a subshell with an azimuthal quantum number of $l = 1$.
- Therefore, any electron in a $4p$ orbital has an azimuthal quantum number of $l = 1$.

Why other options are incorrect:

- Option A:** $l = 0$ designates spherical s subshells.
- Option C:** $l = 2$ designates diffuse d subshells.
- Option D:** $l = 3$ designates fundamental f subshells.

Question #59 Key: (B)

CHEMISTRY
02. Atomic Structure

Which transition element corresponds to the ground-state electron configuration [Formula]?

CORE CONCEPT & DERIVATION

The identity of a neutral atom is determined by its atomic number (Z), which equals the total number of electrons in its ground-state configuration.

Formula / Rule / Reaction:

$$Z = Z_{[\text{Kr}]} + 2 + 5 = 36 + 2 + 5 = 43$$

Solution:

- Krypton has an atomic number of $Z = 36$.
- Adding the valence electrons: 36 (core) + 2 ($5s$) + 5 ($4d$) = 43 total electrons.
- An atomic number of $Z = 43$ corresponds to the transition metal technetium (Tc).

Why other options are incorrect:

- Option A:** Strontium has $Z = 38$ with configuration $[\text{Kr}] 5s^2$.
- Option C:** Ruthenium has $Z = 44$ with anomalous ground-state configuration $[\text{Kr}] 5s^1 4d^7$.
- Option D:** Palladium has $Z = 46$ with ground-state configuration $[\text{Kr}] 4d^{10}$.

Question #60 Key: (A)

CHEMISTRY
02. Atomic Structure

Choose the permitted (physically allowed) set of quantum numbers for an electron in an atom:

CORE CONCEPT & DERIVATION

Electronic states are constrained by quantum mechanical boundary conditions: $n \geq 1$, $0 \leq l \leq n-1$, $-l \leq m_l \leq +l$, and $s = \pm \frac{1}{2}$.

Formula / Rule / Reaction:

$$l \in \{0, 1, \dots, n-1\}, \quad m_l \in \{-l, \dots, 0, \dots, +l\}, \quad s = \pm \frac{1}{2}$$

Solution:

- For Option A: $n = 3$. Allowed l values are 0, 1, 2. Here $l = 2$ (valid).
- When $l = 2$, allowed m_l values are $-2, -1, 0, +1, +2$. Here $m_l = 0$ (valid).
- Spin quantum number $s = +1/2$ is allowed.
- Therefore, this set describes an allowed electron state in a $3d$ orbital.

Why other options are incorrect:

- Option B:** l cannot equal n ; for $n = 3$, the maximum allowed value of l is 2.
- Option C:** m_l cannot exceed l ; for $l = 3$, the maximum allowed m_l is $+3$.
- Option D:** For $l = 2$, m_l is restricted between -2 and $+2$; $m_l = +3$ is invalid.

Question #61 Key: (C)

CHEMISTRY
04. Gases

An ideal gas occupies a volume of [Formula] at [Formula]. At what temperature will the volume ...

CORE CONCEPT & DERIVATION

Charles's law states that the volume of a fixed mass of an ideal gas is directly proportional to its absolute temperature in Kelvin when pressure remains constant.

Formula / Rule / Reaction:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \Rightarrow T_2 = T_1 \left(\frac{V_2}{V_1} \right)$$

Solution:

- Convert initial temperature to Kelvin:

$$T_1 = 10^\circ\text{C} + 273.15 = 283.15 \text{ K}$$

- The volume is halved:

$$V_1 = 10 \text{ dm}^3, \quad V_2 = 5 \text{ dm}^3 \Rightarrow \frac{V_2}{V_1} = 0.5$$

- Solve for final temperature T_2 :

$$T_2 = 283.15 \text{ K} \times 0.5 = 141.575 \text{ K} \approx 141.58 \text{ K}$$

Why other options are incorrect:

- Option A:** 283.15 K is the initial temperature before cooling.
- Option B:** 566.30 K is the temperature required to double the volume, not halve it.
- Option D:** 373.15 K is the normal boiling point of water.

Question #62 Key: (A)

CHEMISTRY
04. Gases

The mathematical relationship between the absolute temperature ([Formula]) and the root mean ...

CORE CONCEPT & DERIVATION

Root mean square velocity is derived from kinetic molecular theory by equating average translational kinetic energy per mole of gas to thermal energy.

Formula / Rule / Reaction:

$$E_k = \frac{1}{2} M c_{\text{rms}}^2 = \frac{3}{2} RT \Rightarrow c_{\text{rms}} = \sqrt{\frac{3RT}{M}}$$

Solution:

- The pressure of an ideal gas from kinetic theory is:

$$P = \frac{1}{3} \frac{Nm}{V} c_{\text{rms}}^2 = \frac{1}{3} \frac{M}{V_m} c_{\text{rms}}^2$$

- Substitute the ideal gas equation $PV_m = RT$:

$$RT = \frac{1}{3} M c_{\text{rms}}^2$$

- Rearranging gives the root mean square velocity:

$$c_{\text{rms}} = \sqrt{\frac{3RT}{M}}$$

Why other options are incorrect:

- Option B:** $\sqrt{2RT/M}$ is the expression for most probable velocity (c_{mp}).
- Option C:** This expression lacks the square root and is dimensionally inconsistent with velocity.
- Option D:** $\sqrt{8RT/(\pi M)}$ represents the average molecular speed (c_{avg}).

Question #63 Key: (A)

CHEMISTRY
05. Liquids

Which of the following unbranched hydrocarbons exhibits the greatest polarizability?

CORE CONCEPT & DERIVATION

Polarizability is the ease with which an external electric field distorts an electron cloud. It increases with molecular size, total electron count, and surface area.

Formula / Rule / Reaction:

$$\text{Polarizability } (\alpha) \propto \text{Number of Electrons} \propto \text{Molecular Weight / Size}$$

Solution:

- Count total electrons per molecule:

$$\text{Hexane (C}_6\text{H}_{14}) = 6(6) + 14(1) = 50 \text{ electrons}$$

$$\text{Butane (C}_4\text{H}_{10}) = 4(6) + 10(1) = 34 \text{ electrons}$$

$$\text{Propane (C}_3\text{H}_8) = 3(6) + 8(1) = 26 \text{ electrons}$$

$$\text{Ethane (C}_2\text{H}_6) = 2(6) + 6(1) = 18 \text{ electrons}$$

- Hexane possesses the largest electron cloud held furthest from its nuclei, making it most easily distorted.
- Therefore, hexane has the highest polarizability and strongest London dispersion forces among the options.

Why other options are incorrect:

- Option B:** Ethane has only 18 electrons and a compact cloud, giving it low polarizability.
- Option C:** Butane has fewer electrons (34) than hexane (50).
- Option D:** Propane has 26 electrons and less polarizable surface area than hexane.

Question #64 Key: (D)

CHEMISTRY
06. Solids

Which of the following solid substances does NOT exhibit a sharp, characteristic molar heat of fusion?

CORE CONCEPT & DERIVATION

Crystalline solids have long-range order and melt at a well-defined temperature with a sharp, characteristic heat of fusion. Amorphous solids lack regular repeating lattices and soften gradually over a temperature range.

Formula / Rule / Reaction:

Qualitative concept / Solid State Chemistry.

Solution:

- NaCl, Al₂O₃, and Fe₂O₃ are crystalline solids with defined crystal lattices.
- They melt at specific melting points with a characteristic molar heat of fusion (ΔH_{fus}).
- Amorphous silicates (such as window glass) possess disordered polymeric networks without sharp phase transitions.
- They soften gradually across a glass transition range rather than possessing a fixed heat of fusion.

Why other options are incorrect:

- Option A:** NaCl is an ionic crystal with a sharp melting point of 801°C and a defined ΔH_{fus} .
- Option B:** Corundum (Al₂O₃) melts sharply at 2072°C with a characteristic ΔH_{fus} .
- Option C:** Hematite (Fe₂O₃) is crystalline with a fixed lattice dissociation enthalpy.

Question #65 Key: (B)

CHEMISTRY
05. Liquids

If the external atmospheric pressure above a liquid is reduced to half its standard value, the ...

CORE CONCEPT & DERIVATION

A liquid boils when its vapor pressure equals the prevailing external pressure. Lowering external pressure allows vapor pressure to match it at a lower temperature, reducing the boiling point.

Formula / Rule / Reaction:

$$\ln\left(\frac{P_2}{P_1}\right) = -\frac{\Delta H_{\text{vap}}}{R} \left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

Solution:

- At standard atmospheric pressure (1 atm), pure ethanol boils at 78.3°C.
- When the external pressure is lowered to 0.5 atm, less thermal energy is needed for vapor pressure to reach external pressure.
- Consequently, ethanol boils at a lower temperature (approximately 63°C to 68°C).

Why other options are incorrect:

- Option A:** Boiling point increases only when external pressure is elevated above 1 atm.
- Option C:** A boiling point of 78.3°C requires an external pressure of exactly 1 atm.
- Option D:** The Clausius-Clapeyron relation is logarithmic with reciprocal absolute temperature (Kelvin), so halving pressure does not halve the Celsius temperature.

Question #66 Key: (A)

CHEMISTRY
06. SolidsSolid iodine (I₂) is a poor electrical conductor primarily because:

CORE CONCEPT & DERIVATION

Electrical conduction requires mobile charge carriers (delocalized electrons or free ions). Molecular crystals consist of neutral molecules with tightly bound valence electrons and cannot conduct electricity.

Formula / Rule / Reaction:

Factual recall / Chemical Bonding.

Solution:

- Solid iodine crystallizes as a face-centered orthorhombic lattice of diatomic I₂ molecules.
- The atoms within each molecule are bonded by localized covalent bonds, with neighboring molecules held by weak London dispersion forces.
- All valence electrons are localized in single bonds or lone pairs.
- Without free electrons or ions, solid iodine acts as an electrical insulator.

Why other options are incorrect:

- Option B:** Iodine is a non-metal that does not adopt metallic bonding or a metallic lattice.
- Option C:** Non-polarity of the covalent bond does not explain electrical conductivity; graphite has non-polar bonds but conducts electricity via delocalized π electrons.
- Option D:** Iodine is a molecular crystal, not an ionic lattice.

Question #67 Key: (C)

CHEMISTRY
06. Solids

Predict the crystal lattice geometry of cesium chloride ([Formula]), which has a cation-to-an...

CORE CONCEPT & DERIVATION

The radius ratio ($r_{\text{cation}}/r_{\text{anion}}$) determines the coordination number and packing geometry of ionic crystals by maximizing attractive forces while minimizing like-ion repulsion.

Formula / Rule / Reaction:

Radius Ratio Rules: $0.225 - 0.414 \Rightarrow \text{CN } 4$, $0.414 - 0.732 \Rightarrow \text{CN } 6$, $0.732 - 1.000 \Rightarrow \text{CN } 8$

Solution:

- The given radius ratio for CsCl is 0.93.
- This value falls in the range $0.732 \leq \frac{r_+}{r_-} < 1.000$.
- This range corresponds to cubic coordination (coordination number 8 : 8).
- In CsCl, each Cs^+ cation sits in a cubic void surrounded by 8 Cl^- anions, forming a body-centered cubic arrangement.

Why other options are incorrect:

- Option A:** Tetrahedral 4 : 4 coordination occurs for radius ratios between 0.225 and 0.414 (e.g., ZnS).
- Option B:** Octahedral 6 : 6 coordination occurs for radius ratios between 0.414 and 0.732 (e.g., NaCl).
- Option D:** Coordination number 12 occurs in close-packed elemental metals, not binary ionic compounds.

Question #68 Key: (B)

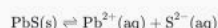
CHEMISTRY
07. Equilibrium

The solubility product constant ([Formula]) of lead(II) sulfide ([Formula]) at [Formula] is...

CORE CONCEPT & DERIVATION

The molar solubility (S) of a 1:1 sparingly soluble salt is related to its solubility product constant by $K_{\text{sp}} = S^2$.

Formula / Rule / Reaction:



$$K_{\text{sp}} = [\text{Pb}^{2+}][\text{S}^{2-}] = (S)(S) = S^2 \Rightarrow S = \sqrt{K_{\text{sp}}}$$

Solution:

- Substitute the given solubility product value:

$$S = \sqrt{4.0 \times 10^{-28}}$$

- Evaluate the square root:

$$S = \sqrt{4.0 \times 10^{-28}} = 2.0 \times 10^{-14} \text{ mol/dm}^3$$

- Therefore, the molar solubility of PbS in pure water is $2.0 \times 10^{-14} \text{ M}$.

Why other options are incorrect:

- Option A:** $4.0 \times 10^{-14} \text{ M}$ takes the square root of the exponent without taking the root of the coefficient.
- Option C:** $1.0 \times 10^{-14} \text{ M}$ miscalculates the root of the coefficient.
- Option D:** $2.0 \times 10^{-28} \text{ M}$ simply divides K_{sp} by two rather than taking its square root.

Question #69 Key: (D)

CHEMISTRY
07. Equilibrium

Which industrial operating conditions are applied in the Haber process to optimize the equilib...

CORE CONCEPT & DERIVATION

Ammonia synthesis is an exothermic equilibrium reaction that proceeds with a decrease in moles of gas. Le Chatelier's principle dictates that high pressure and low temperature maximize equilibrium yield, though a compromised moderate temperature is needed to maintain reaction rate.

Formula / Rule / Reaction:



Solution:

- Four moles of gaseous reactants yield two moles of product; high pressure (200 atm) shifts equilibrium forward.
- The forward reaction is exothermic, so low temperatures favor higher equilibrium concentrations of ammonia.
- However, low temperatures reduce reaction rate; therefore, a compromise temperature of 400°C to 450°C is used alongside a finely divided iron catalyst.

Why other options are incorrect:

- Option A:** A temperature of 500°C shifts the equilibrium backward, reducing equilibrium conversion.
- Option B:** At 200°C , the reaction rate is too slow for commercial operation, even with a catalyst.
- Option C:** 100 atm produces a lower equilibrium yield than standard industrial 200 atm operations.

Question #70 Key: (D)

CHEMISTRY
07. Equilibrium

Which of the following aqueous buffer solutions possesses the HIGHEST [Formula] ? ([Formula])

CORE CONCEPT & DERIVATION

The pH of an acidic buffer is governed by the Henderson-Hasselbalch equation and increases directly with the ratio of conjugate base to weak acid.

Formula / Rule / Reaction:

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

Solution:

- Calculate the base-to-acid ratio for each solution:

$$\text{Option A: } \frac{0.01}{0.10} = 0.10 \Rightarrow \log(0.10) = -1.00$$

$$\text{Option B: } \frac{0.05}{0.10} = 0.50 \Rightarrow \log(0.50) = -0.30$$

$$\text{Option C: } \frac{0.10}{0.10} = 1.00 \Rightarrow \log(1.00) = 0.00$$

$$\text{Option D: } \frac{0.15}{0.10} = 1.50 \Rightarrow \log(1.50) = +0.18$$

- Option D has the largest base-to-acid ratio, producing the highest pH ($\text{pH} = \text{p}K_{\text{a}} + 0.18$).

Why other options are incorrect:

- Option A:** Having the smallest base-to-acid ratio makes this buffer the most acidic (lowest pH).
- Option B:** A ratio of 0.50 yields a pH below the $\text{p}K_{\text{a}}$.
- Option C:** Equal concentrations of acid and conjugate base produce a pH exactly equal to $\text{p}K_{\text{a}}$ (4.74), which is lower than Option D.

Question #71 Key: (D)

CHEMISTRY
08. Reaction Kinetics

The initial rate of hydrogen gas evolution during the reaction of [Formula] of zinc with [Formu...

CORE CONCEPT & DERIVATION

Heterogeneous reaction rates are directly proportional to the surface area of the solid reactant. Subdividing a solid increases the number of exposed atoms available for reactant collisions.

Formula / Rule / Reaction:



$$\text{Rate} \propto \text{Surface Area} \times \text{Collision Frequency}$$

Solution:

- Fine zinc powder has the highest specific surface area per unit mass among all the samples.
- A larger surface area exposes more zinc atoms to collision with aqueous hydronium ions.
- This increases the frequency of effective collisions, resulting in the fastest initial rate of H_2 gas evolution.

Why other options are incorrect:

- Option A:** A solid rod has the smallest surface-area-to-mass ratio, producing the slowest initial reaction rate.
- Option B:** Pellets have a relatively low surface area compared to finely divided powders.
- Option C:** Thin ribbons offer moderate surface area, but far less than fine microparticulate powder.

Question #72 Key: (C)

CHEMISTRY
08. Reaction KineticsConsider the photosynthetic reaction: $6\text{CO}_2\text{(g)} + 6\text{H}_2\text{O(l)} \xrightarrow{\text{light}}$

CORE CONCEPT & DERIVATION

Photochemical reactions under light-saturating conditions proceed at a rate determined by photon flux and enzyme saturation, remaining independent of reactant concentrations.

Formula / Rule / Reaction:

$$\text{Rate} = k[\text{CO}_2]^0[\text{H}_2\text{O}]^0 = k \quad (\text{Zero-order kinetics})$$

Solution:

- Photosynthesis is driven by light absorption by thylakoid pigments rather than simple thermal collisions.
- When light and enzyme active sites are saturated, further increases in CO_2 or H_2O concentration do not accelerate the rate.
- Because the rate is independent of reactant concentration, the reaction follows zero-order kinetics.

Why other options are incorrect:

- Option A:** First-order reactions have rates directly proportional to a single reactant concentration.
- Option B:** Second-order reactions depend on the square of one concentration or the product of two.
- Option D:** Third-order kinetics would require a trimolecular rate-determining step, which does not occur here.

Question #73 Key: (A)

CHEMISTRY
08. Reaction Kinetics

Which of the following reaction mechanisms is consistent with the experimentally observed rate ...

CORE CONCEPT & DERIVATION

The rate law of a multi-step chemical reaction is determined by the molecularity of its slowest elementary step (the rate-determining step).

Formula / Rule / Reaction:



Solution:

- In Option A, the slow rate-determining step is:



- The molecularity involves two molecules of NO and one molecule of H_2 .
- Writing the rate law directly from this elementary slow step gives:

$$\text{Rate} = k[\text{NO}]^2[\text{H}_2]$$

- This matches the experimentally observed rate law.

Why other options are incorrect:

- Option B:** This slow step gives $\text{Rate} = k[\text{NO}][\text{H}_2\text{O}]$, which is first order in NO.
- Option C:** A slow step involving two NO and two H_2 would give $\text{Rate} = k[\text{NO}]^2[\text{H}_2]^2$.
- Option D:** A slow step involving only two NO molecules gives $\text{Rate} = k[\text{NO}]^2$, independent of $[\text{H}_2]$.

Question #74 Key: (B)

CHEMISTRY
09. ThermochemistryGiven the following thermochemical data: $2\text{HI(g)} \longrightarrow \text{H}_2\text{(g)} + \text{I}_2\text{(s)}$ $\Delta H^\circ_{\text{rxn}} = -10.5 \text{ kJ/mol}$

CORE CONCEPT & DERIVATION

Hess's law of constant heat summation states that the total enthalpy change for a chemical process is independent of the pathway taken between initial and final states.

Formula / Rule / Reaction:



$$\Delta H^\circ_{\text{sub}} = \Delta H^\circ_1 - \Delta H^\circ_2$$

Solution:

- Equation (1): $\text{H}_2\text{(g)} + \text{I}_2\text{(s)} \longrightarrow 2\text{HI(g)} \quad \Delta H^\circ_1 = +51.8 \text{ kJ/mol}$
- Reverse Equation (2): $2\text{HI(g)} \longrightarrow \text{H}_2\text{(g)} + \text{I}_2\text{(g)} \quad -\Delta H^\circ_2 = +10.5 \text{ kJ/mol}$
- Add both equations:



$$\Delta H^\circ_{\text{sub}} = +51.8 \text{ kJ/mol} + (+10.5 \text{ kJ/mol}) = +62.3 \text{ kJ/mol}$$

Why other options are incorrect:

- Option A:** $+41.3 \text{ kJ/mol}$ incorrectly subtracts 10.5 from 51.8, failing to reverse the sign when reversing equation (2).
- Option C:** -62.3 kJ/mol represents exothermic deposition (gas to solid) rather than endothermic sublimation.
- Option D:** $+36.5 \text{ kJ/mol}$ is an arithmetic error.

Question #75 Key: (B)

CHEMISTRY
09. Thermochemistry

Which of the following chemical equations represents a standard enthalpy of reaction that is NO...

CORE CONCEPT & DERIVATION

The standard enthalpy of formation (ΔH_f°) is defined as the enthalpy change when one mole of a compound is formed from its constituent elements in their standard reference states.

Formula / Rule / Reaction:

$$\Delta H_{\text{rxn}}^\circ = \Delta H_f^\circ \iff \text{Reactants are pure elements in standard reference states}$$

Solution:

- In Option B, carbon monoxide (CO) is a stable compound, not an element in its standard state.
- Therefore, the reaction $\text{CO(g)} + \frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)}$ represents the standard enthalpy of combustion of CO, not the standard enthalpy of formation of CO_2 .
- In contrast, options A, C, and D form one mole of product directly from pure elements in their standard states.

Why other options are incorrect:

- Option A:** $\text{H}_2\text{(g)}$ and $\text{O}_2\text{(g)}$ are pure elements in their standard states, making this reaction the standard enthalpy of formation of liquid water.
- Option C:** Graphite and oxygen gas are the standard reference states of carbon and oxygen, making this the standard enthalpy of formation of CO_2 .
- Option D:** Rhombic sulfur and oxygen gas are elements in standard states, representing the enthalpy of formation of SO_2 .

Question #76 Key: (D)

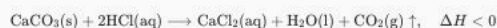
CHEMISTRY
09. Thermochemistry

Gaseous expansion occurs when carbon dioxide gas is evolved during the reaction between marble ...

CORE CONCEPT & DERIVATION

The reaction between calcium carbonate and hydrochloric acid is exothermic, releasing thermal energy to the surroundings. When evolved gas expands against external atmospheric pressure, the system does work on the surroundings.

Formula / Rule / Reaction:



$$w = -P_{\text{ext}}\Delta V \quad (\Delta V > 0 \implies w < 0), \quad q_{\text{sys}} < 0$$

Solution:

- The dissolution of marble chips in acid releases heat, making the process exothermic; hence, heat released by the system carries a negative sign ($q < 0$).
- Carbon dioxide gas is produced, increasing the volume of the system against external pressure ($\Delta V > 0$).
- Under IUPAC thermodynamic conventions, work done by the system on the surroundings is negative ($w = -P\Delta V < 0$).
- Therefore, both w and q are negative.

Why other options are incorrect:

- Option A:** Work done by the system is negative under IUPAC convention, not positive.
- Option B:** Heat is released, not absorbed; an endothermic sign ($q > 0$) is incorrect.
- Option C:** Gaseous expansion against atmospheric pressure performs mechanical $P\Delta V$ work; work is not zero.

Question #77 Key: (A)

CHEMISTRY
10. Electrochemistry

A zinc rod acts as the cathode when coupled with a magnesium electrode in a standard galvanic cell...

CORE CONCEPT & DERIVATION

In an electrochemical galvanic cell, the half-cell with the higher (more positive or less negative) standard reduction potential undergoes reduction and functions as the cathode.

Formula / Rule / Reaction:

$$E^\circ(\text{Zn}^{2+}/\text{Zn}) = -0.76 \text{ V}, \quad E^\circ(\text{Mg}^{2+}/\text{Mg}) = -2.37 \text{ V}$$

$$E_{\text{cathode}}^\circ > E_{\text{anode}}^\circ \implies -0.76 \text{ V} > -2.37 \text{ V}$$

Solution:

- The standard reduction potential of zinc (-0.76 V) is greater (less negative) than that of magnesium (-2.37 V).
- Magnesium oxidizes more readily and acts as the anode: $\text{Mg} \rightarrow \text{Mg}^{2+} + 2e^-$.
- Zinc ions accept electrons and undergo reduction at the zinc electrode: $\text{Zn}^{2+} + 2e^- \rightarrow \text{Zn}$.
- Because reduction occurs at the cathode, the zinc rod serves as the cathode.

Why other options are incorrect:

- Option B:** If zinc had a lower reduction potential than magnesium, zinc would oxidize and serve as the anode.
- Option C:** Equal reduction potentials would yield a net cell potential of zero, preventing current flow.
- Option D:** Standard hydrogen electrode (SHE) is assigned a potential of zero, not zinc.

Question #78 Key: (A)

CHEMISTRY
10. Electrochemistry

Placing a clean iron rod into an aqueous blue solution of copper(II) sulfate ([Formula]) resu...

CORE CONCEPT & DERIVATION

A metal higher in the electrochemical activity series (more negative standard reduction potential) displaces a less reactive metal cation from aqueous solution via spontaneous redox displacement.

Formula / Rule / Reaction:



Solution:

- Iron has a lower reduction potential ($E^\circ = -0.44 \text{ V}$) than copper ($E^\circ = +0.34 \text{ V}$), making iron a stronger reducing agent.
- Iron atoms lose electrons and dissolve into solution as green Fe^{2+} ions.
- Copper(II) ions in solution are reduced, depositing a reddish layer of metallic copper on the iron rod.

Why other options are incorrect:

- Option B:** Iron undergoes oxidative dissolution into Fe^{2+} ions; it does not precipitate as metallic iron.
- Option C:** Copper ions precipitate out of solution while iron dissolves; both do not dissolve together.
- Option D:** Iron is more reactive (more electropositive) than copper, driving a spontaneous displacement reaction.

Question #79 Key: (D)

CHEMISTRY
03. Chemical Bonding

In chloromethane (CH_3Cl), the experimental bond length is 176.7 pm . If the si...

CORE CONCEPT & DERIVATION

The bond length between two covalently bonded atoms is approximately equal to the sum of their individual single-bond covalent radii.

Formula / Rule / Reaction:

$$d_{\text{C-Cl}} = r_{\text{cov}}(\text{C}) + r_{\text{cov}}(\text{Cl}) \implies r_{\text{cov}}(\text{C}) = d_{\text{C-Cl}} - r_{\text{cov}}(\text{Cl})$$

Solution:

- Given bond length: $d_{\text{C-Cl}} = 176.7 \text{ pm}$.
- Given chlorine covalent radius: $r_{\text{cov}}(\text{Cl}) = 99.4 \text{ pm}$.
- Subtract the chlorine radius from the total bond length:

$$r_{\text{cov}}(\text{C}) = 176.7 \text{ pm} - 99.4 \text{ pm} = 77.3 \text{ pm}$$

- This matches the standard tetrahedral sp^3 covalent radius of carbon (77 pm).

Why other options are incorrect:

- Option A:** 66.3 pm is the covalent radius of oxygen, not carbon.
- Option B:** 276.1 pm adds the radii together rather than subtracting.
- Option C:** 175.4 pm represents an arithmetic error.

Question #80 Key: (B)

CHEMISTRY
03. Chemical Bonding

Which of the following sequences correctly represents the decreasing order of electron affinity...

CORE CONCEPT & DERIVATION

Electron affinity generally decreases down a group due to increasing atomic radius. However, fluorine exhibits an anomaly: its compact $2p$ subshell creates high electron density that repels an incoming electron, giving chlorine a higher electron affinity.

Formula / Rule / Reaction:

$$\text{Electron Affinities (kJ/mol): } \text{Cl} (-349) > \text{F} (-328) > \text{Br} (-325) > \text{I} (-295)$$

Solution:

- Chlorine has a spacious $3p$ subshell that accepts an additional electron with minimal interelectronic repulsion (-349 kJ/mol).
- Fluorine has a smaller $2p$ orbital volume, resulting in significant electron-electron repulsion that lowers the energy released upon electron capture (-328 kJ/mol).
- Down the group past chlorine, increasing atomic radius and shielding decrease nuclear attraction for incoming electrons: $\text{Br} > \text{I}$.
- The resulting order of decreasing electron affinity is $\text{Cl} > \text{F} > \text{Br} > \text{I}$.

Why other options are incorrect:

- Option A:** Fails to account for the fluorine anomaly caused by $2p$ interelectronic repulsion.
- Option C:** Inverts the periodic trend, listing the lowest affinity halogen first.
- Option D:** Incorrectly places bromine ahead of fluorine.

Question #81 Key: (A)

CHEMISTRY
03. Chemical Bonding

Which of the following single covalent bonds exhibits the HIGHEST bond dissociation energy?

CORE CONCEPT & DERIVATION

Bond dissociation energy is inversely related to bond length and directly proportional to orbital overlap efficiency. The small atomic radius of hydrogen produces a very short, strong bond with carbon.

Formula / Rule / Reaction:

$$\text{Bond Energies (kJ/mol): } \text{C-H} (\approx 413) > \text{C-O} (\approx 358) > \text{C-C} (\approx 348) > \text{C-N} (\approx 305)$$

Solution:

- The hydrogen $1s$ orbital is small, allowing close approach to the carbon sp^3 hybrid orbital.
- This produces a short bond length ($\approx 109 \text{ pm}$) and effective orbital overlap.
- In contrast, second-period atoms (C, N, O) have larger $2p$ orbitals and longer bond lengths (143 to 154 pm).
- Therefore, the C-H single bond requires the greatest energy to cleave homolytically (413 kJ/mol).

Why other options are incorrect:

- Option B:** The C-N single bond is longer and weaker, with a bond energy of 305 kJ/mol .
- Option C:** The C-O single bond has a bond energy of approximately 358 kJ/mol , lower than C-H .
- Option D:** The non-polar C-C single bond has a bond energy of 348 kJ/mol .

Question #82 Key: (A)

CHEMISTRY
03. Chemical Bonding

Identify the orbital hybridization state of the central nitrogen atom in a diazonium cation or ...

CORE CONCEPT & DERIVATION

Hybridization is determined by the steric number of the central atom (the sum of bonded atoms and non-bonding lone pairs). A nitrogen atom forming one single bond and one triple bond has a steric number of 2.

Formula / Rule / Reaction:

$$\text{Steric Number} = (\sigma\text{-bonds}) + (\text{lone pairs}) = 2 + 0 = 2 \implies \text{sp hybridization}$$

Solution:

- In the linear linkage $[\text{N} \equiv \text{N}^+ - \text{Cl}^-]$, the central nitrogen forms one σ -bond to chlorine and one σ -bond to terminal nitrogen.
- The remaining two bonds to terminal nitrogen are perpendicular π -bonds formed by unhybridized $2p_y$ and $2p_z$ orbitals.
- With zero non-bonding lone pairs on the central nitrogen atom, its steric number is 2.
- A steric number of 2 corresponds to sp hybridization with a linear 180° geometry.

Why other options are incorrect:

- Option B:** sp^2 hybridization requires a steric number of 3 (trigonal planar arrangement).
- Option C:** sp^3 hybridization requires a steric number of 4 (tetrahedral geometry).
- Option D:** dsp^2 hybridization occurs in transition metal square planar complexes and is impossible for second-period elements lacking d -orbitals.

Question #83 Key: (D)

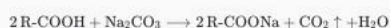
CHEMISTRY
18. Carboxylic Acids

An unknown organic compound X reacts with sodium carbonate ([Formula]) according to the react...

CORE CONCEPT & DERIVATION

Carboxylic acids are sufficiently acidic to decompose inorganic carbonates and bicarbonates, liberating carbon dioxide gas and forming water and a carboxylate salt.

Formula / Rule / Reaction:



Solution:

- Among typical organic functional groups, carboxylic acids ($\text{p}K_a \approx 4$ to 5) react briskly with carbonates.
- Alkenes, aldehydes, and esters lack an acidic proton and do not release CO_2 from sodium carbonate.
- Propanoic acid ($\text{CH}_3\text{CH}_2\text{COOH}$) reacts with Na_2CO_3 to yield sodium propanoate (Compound Y), CO_2 , and H_2O .
- Therefore, Compound X is propanoic acid.

Why other options are incorrect:

- Option A:** 1-butene is a neutral hydrocarbon that does not react with metal carbonates.
- Option B:** Propanal is an aldehyde and does not decompose carbonate salts.
- Option C:** Methyl acetate is an ester; neutral esters do not liberate CO_2 gas with carbonate salts.

Question #84 Key: (A)

CHEMISTRY
17. Aldehydes & Ketones

Consider the haloform reaction sequence: $\text{Compound A} + 3\text{I}_2 + 4\text{NaOH} \longrightarrow \text{Compound B} + \text{CHI}_3 \downarrow + 3\text{NaI} + 3\text{H}_2\text{O}$

CORE CONCEPT & DERIVATION

The iodoform test is specific for compounds containing a methyl carbonyl group ($\text{CH}_3 - \text{C} = \text{O}$) or a secondary alcohol that can be oxidized to one ($\text{CH}_3 - \text{CH}(\text{OH}) -$).

Formula / Rule / Reaction:



Solution:

- Acetone contains the requisite methyl ketone moiety ($\text{CH}_3 - \text{CO} - \text{CH}_3$).
- Under basic iodination, its α -methyl protons are substituted by iodine to form a triiodomethyl intermediate.
- Hydroxide nucleophilic attack cleaves the carbon-carbon bond, precipitating yellow iodoform (CHI_3 , Compound B).
- Carboxylic acids and their derivatives (amides, anhydrides) do not undergo the haloform reaction due to resonance stabilization of the acyl group.

Why other options are incorrect:

- Option B:** Acetic acid contains a carboxyl group rather than a methyl ketone and tests negative in haloform tests.
- Option C:** Acetamide has an amide nitrogen that donates electrons via resonance, preventing triiodination.
- Option D:** Acetic anhydride hydrolyzes in aqueous base without forming a haloform precipitate.

Question #85 Key: (A)

CHEMISTRY
18. Carboxylic Acids

Which of the following aliphatic carboxylic acids has the HIGHEST melting point?

CORE CONCEPT & DERIVATION

The melting points of aliphatic carboxylic acids show an alternating (sawtooth) pattern based on carbon number. Even-carbon acids pack more symmetrically into crystalline lattices, giving ethanoic acid a notably high melting point.

Formula / Rule / Reaction:

Melting Points: Ethanoic (16.6°C) > Butanoic (-5.2°C) > Propanoic (-21.5°C) > Pentanoic (-34.5°C)

Solution:

- Ethanoic acid (acetic acid) has two carbons, allowing it to pack tightly into a stable crystal lattice held by cyclic hydrogen-bonded dimers.
- Its melting point is 16.6°C , freezing into ice-like crystals at cool room temperature (glacial acetic acid).
- Propanoic acid (3 carbons) and pentanoic acid (5 carbons) have odd numbers of carbons, disrupting crystal packing and lowering their melting points to -21.5°C and -34.5°C .
- Therefore, ethanoic acid has the highest melting point among the given options.

Why other options are incorrect:

- Option B:** Propanoic acid melts at -21.5°C due to odd-carbon lattice packing effects.
- Option C:** Butanoic acid melts at -5.2°C , lower than ethanoic acid.
- Option D:** Pentanoic acid melts at -34.5°C .

Question #86 Key: (C)

CHEMISTRY
18. Carboxylic Acids

Which of the following organic compounds possesses the SHORTEST carbon-heteroatom ([Formula]) bond?

CORE CONCEPT & DERIVATION

Bond length decreases with increasing bond order. Carbonyl double bonds ($\text{C} = \text{O}$) are shorter than single bonds, and in formic acid the $\text{C} = \text{O}$ bond has minimal resonance lengthening compared to amides.

Formula / Rule / Reaction:

$d(\text{C} = \text{O} \text{ in } \text{HCOOH}) \approx 120.2 \text{ pm} < d(\text{C} = \text{O} \text{ in } \text{HCONH}_2) \approx 124 \text{ pm} < d(\text{C} - \text{N}) \approx 147 \text{ pm}$

Solution:

- Methylamine and ethanol contain single $\text{C} - \text{N}$ (147 pm) and $\text{C} - \text{O}$ (143 pm) bonds.
- Formamide and formic acid contain carbonyl double bonds ($\text{C} = \text{O}$), which are substantially shorter than single bonds.
- In formamide, strong resonance donation from nitrogen ($\text{O} = \text{C} - \text{NH}_2 \longleftrightarrow \text{O}^- - \text{C} = \text{NH}_2^+$) lengthens the $\text{C} = \text{O}$ bond to $\approx 124 \text{ pm}$.
- In formic acid, the less electropositive oxygen atom donates less resonance density, leaving the $\text{C} = \text{O}$ bond shorter at 120.2 pm.

Why other options are incorrect:

- Option A:** The $\text{C} - \text{N}$ single bond in methylamine is approximately 147 pm.
- Option B:** The carbonyl bond in formamide is lengthened to 124 pm by amide resonance.
- Option D:** The $\text{C} - \text{O}$ single bond in ethanol measures approximately 143 pm.

Question #87 Key: (C)

CHEMISTRY
14. Hydrocarbons

Identify the alkene that produces only a SINGLE type of aldehyde upon ozonolysis followed by re...

CORE CONCEPT & DERIVATION

Ozonolysis cleaves carbon-carbon double bonds to form carbonyl fragments. A symmetrical alkene with identical, singly substituted sp^2 carbons ($=CH-R$) produces two equivalents of a single aldehyde.

Formula / Rule / Reaction:



Solution:

- 2-butene ($CH_3CH=CHCH_3$) is symmetrical across its central double bond.
- Reductive cleavage splits the double bond, converting each $=CH-CH_3$ unit into an acetaldehyde molecule (CH_3CHO).
- This yields acetaldehyde as the sole aldehyde product.

Why other options are incorrect:

- Option A:** 1-pentene cleaves unsymmetrically to yield formaldehyde ($HCHO$) and butanal ($CH_3CH_2CH_2CHO$), two different aldehydes.
- Option B:** 2-methylpropene yields one aldehyde ($HCHO$) and one ketone (acetone).
- Option D:** 2,3-dimethyl-2-butene has tetrasubstituted carbons, yielding two molecules of acetone (a ketone, not an aldehyde).

Question #88 Key: (D)

CHEMISTRY
17. Aldehydes & Ketones

What is the correct order of INCREASING reactivity of carbonyl compounds toward nucleophilic ad...

CORE CONCEPT & DERIVATION

Reactivity toward nucleophilic addition depends on the electrophilicity of the carbonyl carbon and steric hindrance around it. Electron-donating alkyl groups and bulky substituents decrease reactivity.

Formula / Rule / Reaction:

$$\text{Reactivity} \propto \frac{1}{\text{Steric Hindrance}} \times \delta^+ \text{ on Carbonyl Carbon}$$

Solution:

- Acetone (CH_3COCH_3) has two electron-donating methyl groups that reduce partial positive charge on the carbonyl carbon and create steric crowding, making it the least reactive.
- Propanal (CH_3CH_2CHO) has an ethyl group with slightly greater steric hindrance than the methyl group of acetaldehyde (CH_3CHO).
- Formaldehyde ($HCHO$) lacks alkyl substituents, providing minimal steric hindrance and the most electrophilic carbonyl carbon.
- The resulting sequence of increasing reactivity is: $CH_3COCH_3 < CH_3CH_2CHO < CH_3CHO < HCHO$.

Why other options are incorrect:

- Option A:** Inverts the reactivity series by placing the most reactive aldehyde first.
- Option B:** Incorrectly lists acetone as more reactive than acetaldehyde.
- Option C:** Incorrectly suggests aldehydes are less reactive than ketones.

Question #89 Key: (A)

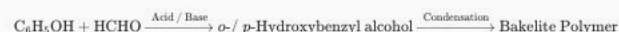
CHEMISTRY
20. Industrial Chemistry

Bakelite, an important thermosetting cross-linked polymer, is manufactured industrially through...

CORE CONCEPT & DERIVATION

Bakelite is a phenol-formaldehyde resin produced by electrophilic aromatic substitution of formaldehyde at the ortho- and para-positions of phenol, followed by condensation into a three-dimensional cross-linked network.

Formula / Rule / Reaction:



Solution:

- Phenol reacts with formaldehyde ($HCHO$) in the presence of an acid or base catalyst to form ortho- and para-hydroxybenzyl alcohols.
- Linear polymerization initially produces Novolac.
- Further heating with excess formaldehyde forms methylene ($-CH_2-$) cross-links between benzene rings.
- This produces Bakelite, a hard, infusible, thermosetting polymer.

Why other options are incorrect:

- Option B:** Phenol and $NaOH$ form sodium phenoxide, not a polymer.
- Option C:** Concentrated sulfuric acid sulfonates phenol to form phenolsulfonic acids.
- Option D:** Acetyl chloride and $AlCl_3$ produce acetophenone derivatives via Friedel-Crafts acylation.

Question #90 Key: (C)

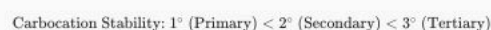
CHEMISTRY
16. Alcohols & Phenols

What is the correct increasing order of reactivity of isomeric hexanols toward nucleophilic sub...

CORE CONCEPT & DERIVATION

Reactions of alcohols involving $C-O$ bond cleavage (such as reaction with hydrogen halides) proceed via carbocation intermediates. Reactivity follows carbocation stability: $1^\circ < 2^\circ < 3^\circ$.

Formula / Rule / Reaction:



Solution:

- 2-methyl-1-pentanol is a primary (1°) alcohol; it forms an unstable primary carbocation, making it the least reactive.
- 3-methyl-2-pentanol is a secondary (2°) alcohol; it forms a moderately stable secondary carbocation.
- 2-methyl-2-pentanol is a tertiary (3°) alcohol; it forms a stable tertiary carbocation, reacting most rapidly.
- The order of increasing reactivity is: $1^\circ < 2^\circ < 3^\circ$ (2-methyl-1-pentanol < 3-methyl-2-pentanol < 2-methyl-2-pentanol).

Why other options are incorrect:

- Option A:** Inverts the order, incorrectly placing the most reactive tertiary alcohol as the least reactive.
- Option B:** Places primary alcohol as more reactive than secondary alcohol.
- Option D:** Places tertiary alcohol as the least reactive.

Question #91 Key: (C)

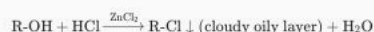
CHEMISTRY
16. Alcohols & Phenols

Which of the following isomeric pentyl alcohols reacts most rapidly with Lucas reagent (anhydro...)

CORE CONCEPT & DERIVATION

The Lucas test distinguishes alcohols based on the rate of S_N1 conversion into insoluble alkyl chlorides. Tertiary alcohols react almost instantaneously at room temperature due to high tertiary carbocation stability.

Formula / Rule / Reaction:



Reactivity: Tertiary (3°) > Secondary (2°) > Primary (1°)

Solution:

- 2-methyl-2-butanol is a tertiary (3°) alcohol.
- Protonation by HCl followed by loss of water yields a stable tertiary carbocation intermediate.
- Chloride attacks rapidly, producing insoluble 2-chloro-2-methylbutane turbidity within seconds at room temperature.
- Secondary alcohols require 5 to 10 minutes, while primary alcohols do not react at room temperature without prolonged heating.

Why other options are incorrect:

- Option A:** 2-butanol is a secondary alcohol that reacts slowly (5 to 10 minutes).
- Option B:** 2-methyl-1-butanol is a primary alcohol that shows no turbidity at room temperature.
- Option D:** 2,2-dimethyl-1-propanol (neopentyl alcohol) is a primary alcohol that remains unreactive at room temperature.

Question #92 Key: (D)

CHEMISTRY
14. Hydrocarbons

Which of the following substituted benzene derivatives undergoes electrophilic aromatic sulfonation...

CORE CONCEPT & DERIVATION

Electrophilic aromatic substitution is accelerated by electron-donating substituents that increase electron density on the benzene ring and stabilize the cationic arenium intermediate.

Formula / Rule / Reaction:

Relative Rates: Toluene ($-CH_3$, activating) > Benzene > Chlorobenzene ($-Cl$) > Nitrobenzene ($-NO_2$)

Solution:

- Toluene possesses a methyl substituent that donates electron density through inductive effects and hyperconjugation.
- This activates the ortho- and para-positions toward electrophilic attack by SO_3 .
- Chlorobenzene is weakly deactivating due to the electronegativity of chlorine.
- Nitrobenzene contains a strongly deactivating, electron-withdrawing nitro group.
- Therefore, toluene sulfonates at the fastest rate.

Why other options are incorrect:

- Option A:** Unsubstituted benzene lacks the activating electron-donating methyl group.
- Option B:** The inductive electron-withdrawing effect of chlorine slows the rate of sulfonation relative to benzene.
- Option C:** The strong $-I$ and $-M$ effects of the nitro group deactivate the ring toward electrophiles.

Question #93 Key: (D)

CHEMISTRY
13. Fundamental Principles of Organic Chemistry

Which of the following alkenes exhibits geometrical (cis-trans) isomerism?

CORE CONCEPT & DERIVATION

Geometrical isomerism in alkenes requires restricted rotation about a carbon-carbon double bond and two non-identical substituent groups attached to each individual sp^2 carbon atom.

Formula / Rule / Reaction:

Requirement: $C_a(R_1 \neq R_2) = C_b(R_3 \neq R_4)$

Solution:

- Structure of 3-methyl-2-pentene: $CH_3-CH=C(CH_3)-CH_2CH_3$.
- C-2 is attached to $-H$ and $-CH_3$ (two different groups).
- C-3 is attached to $-CH_3$ and $-CH_2CH_3$ (two different groups).
- Because both sp^2 carbons bear non-identical substituents, 3-methyl-2-pentene exists as distinct cis/trans (or E/Z) isomers.

Why other options are incorrect:

- Option A:** 3-methyl-1-butene has two identical hydrogen atoms on C-1 ($=CH_2$), preventing geometrical isomerism.
- Option B:** Methylcyclopentane is a saturated cycloalkane without a double bond.
- Option C:** 2,3-dimethyl-2-butene has two identical methyl groups on each double-bonded carbon.

Question #94 Key: (A)

CHEMISTRY
11. S & P Block Elements

What is the correct sequence of INCREASING first ionization energies for the third-period elements...

CORE CONCEPT & DERIVATION

First ionization energy generally increases across a period with increasing effective nuclear charge, but dips when removing an electron from a new subshell (such as $3p$ after a stable filled $3s^2$ subshell).

Formula / Rule / Reaction:

Values (kJ/mol): Na (496) < Al (578) < Mg (738) < Si (786)

Solution:

- Sodium has the lowest ionization energy (496 kJ/mol) due to its larger radius and single valence electron.
- Magnesium has configuration $[Ne] 3s^2$ with a completely filled, stable $3s$ subshell (738 kJ/mol).
- Aluminium has configuration $[Ne] 3s^2 3p^1$; its lone $3p$ electron is shielded by the $3s^2$ pair, lowering its ionization energy (578 kJ/mol) below that of magnesium.
- Silicon ($[Ne] 3s^2 3p^2$) experiences higher effective nuclear charge, raising its ionization energy to 786 kJ/mol.
- The correct order is $Na < Al < Mg < Si$.

Why other options are incorrect:

- Option B:** Does not account for the subshell dip between magnesium and aluminium.
- Option C:** Places sodium as having the highest ionization energy, which is contrary to periodic trends.
- Option D:** Places aluminium lower than sodium, which is incorrect.

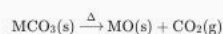
Question #95 Key: (C)CHEMISTRY
11. S & P Block Elements

Which of the following alkaline earth metal carbonates undergoes thermal decomposition most readily...

CORE CONCEPT & DERIVATION

Thermal stability of Group 2 carbonates increases down the group. Cations with higher charge density exert greater polarizing power on the carbonate anion, facilitating decomposition into the metal oxide and CO_2 .

Formula / Rule / Reaction:



Thermal Stability: $\text{BeCO}_3 < \text{MgCO}_3 < \text{CaCO}_3 < \text{SrCO}_3 < \text{BaCO}_3$

Solution:

- Be^{2+} has the smallest ionic radius in Group 2, giving it the highest charge density.
- Its strong polarizing field polarizes the electron cloud of the CO_3^{2-} ion, weakening C – O bonds.
- Consequently, BeCO_3 is unstable at standard conditions and decomposes at temperatures below 100°C .
- Carbonates of larger cations (Mg^{2+} , Sr^{2+} , Ba^{2+}) have lower charge density and require much higher temperatures to decompose.

Why other options are incorrect:

- **Option A:** BaCO_3 is very stable and requires heating above 1300°C to decompose.
- **Option B:** MgCO_3 decomposes at $\approx 540^\circ\text{C}$, far above beryllium carbonate.
- **Option D:** SrCO_3 decomposes only at temperatures above 1200°C .

Question #96 Key: (B)PHYSICS
03. Work & Energy

At what angle between the applied force vector and the displacement vector will the mechanical work be maximum...

CORE CONCEPT & DERIVATION

Work done by a constant force is the scalar dot product of the force and displacement vectors, varying with the cosine of the angle between them.

Formula / Rule / Reaction:

$$W = Fd \cos \theta, \quad W_{\text{max}} = Fd \quad (\text{when } \theta = 0^\circ)$$

$$W = 0.50 W_{\text{max}} \implies \cos \theta = 0.50$$

Solution:

- Maximum work occurs when force and displacement are parallel ($\theta = 0^\circ$, $\cos 0^\circ = 1$).
- Set the work done equal to half of maximum:

$$Fd \cos \theta = 0.50(Fd) \implies \cos \theta = \frac{1}{2}$$

- Taking the inverse cosine:

$$\theta = \arccos(0.50) = 60^\circ$$

Why other options are incorrect:

- **Option A:** At 30° , $\cos 30^\circ = \frac{\sqrt{3}}{2} \approx 0.866$ (86.6% of maximum work).
- **Option C:** At 90° , $\cos 90^\circ = 0$ (zero work done).
- **Option D:** At 45° , $\cos 45^\circ = \frac{1}{\sqrt{2}} \approx 0.707$ (70.7% of maximum work).

Question #97 Key: (C)PHYSICS
03. Work & Energy

What is the average power output of an industrial electric motor that performs [Formula] of mechanical work in [Formula] of time...

CORE CONCEPT & DERIVATION

Power is the rate at which work is performed or energy is transferred per unit time.

Formula / Rule / Reaction:

$$P = \frac{W}{\Delta t}$$

Solution:

- Given work: $W = 64 \times 10^6 \text{ J}$.
- Given time interval: $\Delta t = 8.0 \text{ s}$.
- Calculate power:

$$P = \frac{64 \times 10^6 \text{ J}}{8.0 \text{ s}} = 8.0 \times 10^6 \text{ W}$$

- Convert to megawatts: $8.0 \times 10^6 \text{ W} = 8.0 \text{ MW}$.

Why other options are incorrect:

- **Option A:** 8.0 kW is off by a factor of 10^3 (represents $8 \times 10^3 \text{ W}$).
- **Option B:** 6.0 MW is an arithmetic error.
- **Option D:** 512 MW multiplies work by time instead of dividing.

Question #98 Key: (D)PHYSICS
03. Work & Energy

The mathematical relationship between kinetic energy ([Formula]) and linear momentum ([Formula]) is...

CORE CONCEPT & DERIVATION

Kinetic energy and linear momentum both depend on an object's mass and velocity. Substituting velocity in terms of momentum yields a direct relationship between kinetic energy and momentum.

Formula / Rule / Reaction:

$$p = mv \implies v = \frac{p}{m}, \quad E_k = \frac{1}{2}mv^2$$

Solution:

- Substitute the expression for velocity into the kinetic energy equation:

$$E_k = \frac{1}{2}m \left(\frac{p}{m} \right)^2$$

- Simplify the algebraic expression:

$$E_k = \frac{1}{2}m \left(\frac{p^2}{m^2} \right) = \frac{p^2}{2m}$$

Why other options are incorrect:

- **Option A:** Contains momentum to the first power, which is dimensionally incorrect.
- **Option B:** Dimensionally inconsistent with energy units.
- **Option C:** Lacks the required factor of 2 in the denominator and has an extra mass term.

Question #99 Key: (B)PHYSICS
03. Work & Energy

When a dolphin leaps straight out of the water, it possesses high kinetic energy at the surface...

CORE CONCEPT & DERIVATION

According to the law of conservation of mechanical energy, an object in projectile motion converts its initial kinetic energy into gravitational potential energy as it rises in a uniform gravitational field.

Formula / Rule / Reaction:

$$E_{\text{total}} = E_k + U_g = \text{constant}$$

$$\text{At apex: } v_y = 0 \implies E_k = 0, \quad U_g = mgh_{\text{max}} = E_{\text{total}}$$

Solution:

- As the dolphin ascends, gravitational acceleration decelerates its vertical velocity.
- At the highest point of a vertical leap, its instantaneous vertical velocity reaches zero.
- Consequently, its vertical kinetic energy is momentarily zero.
- By conservation of mechanical energy, that kinetic energy has been converted into maximum gravitational potential energy (mgh).

Why other options are incorrect:

- Option A:** Vertical kinetic energy reaches zero at the apex because vertical velocity is zero.
- Option C:** Elastic potential energy requires a deformed spring or elastic medium, which is not present here.
- Option D:** Chemical bond energy is stored in molecules and is not the mechanical energy term that varies with height.

Question #100 Key: (B)PHYSICS
03. Work & Energy

The absolute gravitational potential energy of a mass [Formula] at a distance [Formula] from the...

CORE CONCEPT & DERIVATION

By convention, gravitational potential energy is defined as zero at an infinite separation. Because gravity is an attractive force, bringing a mass from infinity toward Earth releases energy, resulting in a negative potential energy.

Formula / Rule / Reaction:

$$U_g(r) = - \int_{\infty}^r \vec{F}_g \cdot d\vec{r} = - \frac{GmM_e}{r}, \quad U_g(\infty) = 0$$

Solution:

- Work must be done by an external agent against the attractive gravitational field to move a mass to infinity.
- Because energy is zero at infinity, any finite separation within the field has an energy less than zero (negative).
- The negative sign indicates that the mass is trapped in an attractive potential well and forms a bound system.

Why other options are incorrect:

- Option A:** A repulsive field produces positive potential energy relative to infinity.
- Option C:** Potential energy decreases (becomes more negative) as r decreases.
- Option D:** Escaping Earth's field corresponds to reaching $r = \infty$ with $U_g = 0$.

Question #101 Key: (B)PHYSICS
04. Rotational & Circular Motion

The instantaneous velocity of an object undergoing uniform circular motion at constant speed is...

CORE CONCEPT & DERIVATION

Velocity is a vector quantity defined by both magnitude and direction. In circular motion, even when speed remains constant, the direction of the velocity vector continuously changes along the tangent.

Formula / Rule / Reaction:

$$\vec{v}(t) = v \hat{u}_t(t), \quad \frac{d\vec{v}}{dt} = \vec{a}_c = -\frac{v^2}{r} \hat{u}_r \neq 0$$

Solution:

- In uniform circular motion, speed (the magnitude of velocity) is constant.
- However, the velocity vector points tangentially to the circular trajectory at every instant.
- Because its direction changes continuously, the velocity vector is not constant.
- This continuous change in velocity defines centripetal acceleration.

Why other options are incorrect:

- Option A:** A vector is constant only if both its magnitude and its direction do not change.
- Option C:** The object is moving at speed $v > 0$; its velocity is non-zero.
- Option D:** Instantaneous velocity is directed tangentially, while centripetal acceleration points radially inward.

Question #102 Key: (C)PHYSICS
02. Force & Motion

During rapid vehicular deceleration, wearing seat belts significantly reduces occupant injury p...

CORE CONCEPT & DERIVATION

According to the impulse-momentum theorem, bringing an occupant to rest requires a fixed change in momentum. Extending the duration of the impact force reduces the peak force exerted on the body.

Formula / Rule / Reaction:

$$J = \Delta p = F_{\text{avg}} \Delta t \implies F_{\text{avg}} = \frac{\Delta p}{\Delta t}$$

Solution:

- When a car stops abruptly, the unrestrained occupant continues moving forward due to inertia.
- A seat belt exerts an opposing backward force across the strong bones of the pelvis and ribcage.
- The belt webbing stretches slightly, extending the deceleration time (Δt).
- Increasing Δt for a given momentum change (Δp) substantially lowers the average impact force (F_{avg}), preventing violent collision with the dashboard.

Why other options are incorrect:

- Option A:** The change in momentum ($m\Delta v$) is determined by initial velocity and mass; the belt does not alter Δp .
- Option B:** The restraining force acts opposite to motion along the longitudinal axis, not perpendicularly.
- Option D:** Inertia is an intrinsic property of mass and cannot be eliminated.

Question #103 Key: (C)PHYSICS
02. Force & Motion

A ball possessing an initial momentum of [Formula] strikes a rigid wall perpendicularly and reb...

CORE CONCEPT & DERIVATION

Linear momentum is a vector quantity. The change in momentum is the vector difference between the final momentum and the initial momentum.

Formula / Rule / Reaction:

$$\Delta p = p_f - p_i$$

Solution:

- Initial momentum: $p_i = +8.0 \text{ kg} \cdot \text{m/s}$.
- Because the collision is perfectly elastic and reverses direction without kinetic energy loss:

$$p_f = -8.0 \text{ kg} \cdot \text{m/s}$$

- Calculate change in momentum:

$$\Delta p = (-8.0) - (+8.0) = -16.0 \text{ kg} \cdot \text{m/s} = -16.0 \text{ N} \cdot \text{s}$$

- The change in momentum is $-16.0 \text{ N} \cdot \text{s}$ (directed away from the wall).

Why other options are incorrect:

- Option A:** $+4.0 \text{ N} \cdot \text{s}$ has no physical basis in this collision.
- Option B:** $-8.0 \text{ N} \cdot \text{s}$ represents final momentum, not the change in momentum.
- Option D:** Momentum is a vector; treating it as a scalar would incorrectly give zero change.

Question #104 Key: (D)PHYSICS
02. Force & Motion

In projectile motion over level ground, at what launch angle ([Formula]) will the maximum hei...

CORE CONCEPT & DERIVATIONThe maximum height and horizontal range of a projectile are trigonometric functions of the launch angle. Setting $H = \frac{1}{4}R$ yields a unique value for $\tan \theta$.

Formula / Rule / Reaction:

$$H = \frac{v_0^2 \sin^2 \theta}{2g}, \quad R = \frac{v_0^2 \sin 2\theta}{g} = \frac{2v_0^2 \sin \theta \cos \theta}{g}$$

$$\frac{H}{R} = \frac{\tan \theta}{4}$$

Solution:

- Given condition: $H = \frac{1}{4}R \implies \frac{H}{R} = \frac{1}{4}$.
- Substitute into the height-to-range ratio formula:

$$\frac{\tan \theta}{4} = \frac{1}{4} \implies \tan \theta = 2$$

- Solve for launch angle θ :

$$\theta = \arctan(2) \approx 63.43^\circ \approx 63^\circ$$

Why other options are incorrect:

- Option A:** At 75° , $H/R = \frac{\tan 75^\circ}{4} \approx 0.933$ (height is nearly equal to range).
- Option B:** At 45° , $\tan 45^\circ = 1 \implies H = \frac{1}{4}R$.
- Option C:** At 60° , $\tan 60^\circ = \sqrt{3} \approx 1.732 \implies H/R \approx 0.433$.

Question #105 Key: (A)PHYSICS
04. Rotational & Circular Motion

An athlete runs along a circular track that has a diameter of [Formula], If she traverses a to...

CORE CONCEPT & DERIVATION

Angular displacement in radians is the ratio of linear arc length traversed to the radius of the circular path.

Formula / Rule / Reaction:

$$s = r\theta \implies \theta = \frac{s}{r}$$

Solution:

- Given track diameter: $d = 20 \text{ m} \implies \text{radius } r = \frac{d}{2} = 10 \text{ m}$.
- Given distance traversed along the circular perimeter: $s = 180 \text{ m}$.
- Calculate angular displacement:

$$\theta = \frac{180 \text{ m}}{10 \text{ m}} = 18 \text{ radians}$$

Why other options are incorrect:

- Option B:** 10 radians mistakenly uses the track radius value as the angular displacement.
- Option C:** 9 radians uses diameter (20 m) instead of radius (10 m) in the denominator.
- Option D:** 36 radians multiplies by radius instead of dividing.

Question #106 Key: (A)PHYSICS
04. Rotational & Circular Motion

The angular displacement swept by the minute hand of a standard clock in exactly one minute of ...

CORE CONCEPT & DERIVATIONThe minute hand of a clock completes one full revolution (360° or 2π radians) in 60 minutes. Its angular velocity is constant.

Formula / Rule / Reaction:

$$\omega = \frac{360^\circ}{60 \text{ min}} = 6^\circ/\text{min}$$

Solution:

- In 60 minutes, the minute hand rotates through 360° .
- Calculate the angle swept in one minute:

$$\theta = \frac{360^\circ}{60} = 6^\circ$$

- In radians, this corresponds to $\theta = \frac{2\pi}{60} = \frac{\pi}{30} \text{ rad}$.

Why other options are incorrect:

- Option B:** 12° corresponds to two minutes of elapsed time.
- Option C:** 30° is the angle between adjacent hour markers (swept in 5 minutes).
- Option D:** 0.5° is the angle swept by the hour hand in one minute ($360^\circ/720 \text{ min}$).

Question #107 Key: (A)PHYSICS
04. Rotational & Circular Motion

To determine the vector direction of angular displacement for a rotating body, one should apply...

CORE CONCEPT & DERIVATION

Angular displacement is an axial vector whose direction is defined along the axis of rotation using the right-hand grip rule.

Formula / Rule / Reaction:

Factual recall / Rotational Kinematics.

Solution:

- Grasp the imaginary axis of rotation with the right hand.
- Curl the four fingers in the direction of the rotational motion.
- The extended thumb points along the axis in the vector direction of angular displacement ($\vec{\theta}$) and angular velocity ($\vec{\omega}$).

Why other options are incorrect:

- **Option B:** Using the left hand reverses the vector direction by 180° , violating standard vector conventions.
- **Option C:** Placing the thumb tangent to the path aligns with linear velocity, not angular displacement.
- **Option D:** Describes a modified Fleming's rule for magnetic force, not rotational kinematics.

Question #108 Key: (D)PHYSICS
04. Rotational & Circular Motion

A particle traverses a circular path of radius [Formula] at a constant linear speed of [Formula]...

CORE CONCEPT & DERIVATION

Linear tangential speed is related to angular velocity by $v = r\omega$, where radius must be expressed in SI base units (meters).

Formula / Rule / Reaction:

$$v = r\omega \implies \omega = \frac{v}{r}$$

Solution:

- Convert radius from centimeters to meters:

$$r = 200 \text{ cm} = 2.0 \text{ m}$$

- Given linear speed: $v = 20 \text{ m/s}$.

- Calculate angular velocity:

$$\omega = \frac{20 \text{ m/s}}{2.0 \text{ m}} = 10 \text{ rad/s}$$

Why other options are incorrect:

- **Option A:** 2.0 rad/s is an arithmetic error.
- **Option B:** 4.0 rad/s incorrectly divides speed by r^2 .
- **Option C:** 200 rad/s fails to convert radius to meters, dividing 200 by 1.

Question #109 Key: (B)PHYSICS
04. Rotational & Circular Motion

By standard vector convention in physics, an anti-clockwise (counter-clockwise) rotation in the...

CORE CONCEPT & DERIVATION

By standard mathematical and physical convention, counter-clockwise rotations are assigned positive signs, corresponding to an axial vector pointing out of the plane toward the observer.

Formula / Rule / Reaction:

$$\text{Counter-Clockwise (CCW)} \implies +\hat{k} \text{ (Positive)}, \quad \text{Clockwise (CW)} \implies -\hat{k} \text{ (Negative)}$$

Solution:

- Applying the right-hand rule to a counter-clockwise rotation, curled fingers follow the motion in the xy -plane.
- The right thumb points outward along the $+z$ -axis (out of the page).
- This direction is defined as positive.

Why other options are incorrect:

- **Option A:** Negative angular displacement corresponds to clockwise rotation (pointing into the page).
- **Option C:** Angular displacement is non-zero whenever rotational motion occurs.
- **Option D:** The sign convention for rotational vectors is defined in vector mechanics.

Question #110 Key: (C)PHYSICS
05. Waves

The speed of sound in solid steel is substantially greater than in air primarily because:

CORE CONCEPT & DERIVATION

The propagation velocity of a mechanical compression wave depends directly on the square root of the medium's elastic modulus and inversely on the square root of its density.

Formula / Rule / Reaction:

$$v = \sqrt{\frac{E}{\rho}}$$

Solution:

- Although solid steel is approximately 6000 times denser than air, its Young's modulus ($E \approx 2 \times 10^{11} \text{ Pa}$) is about 1.4×10^6 times larger than the bulk modulus of air ($1.4 \times 10^5 \text{ Pa}$).
- Because the elastic modulus increases by a far greater factor than density, the ratio E/ρ is much larger for steel.
- Consequently, sound travels at $\approx 5100 \text{ m/s}$ in steel compared to $\approx 343 \text{ m/s}$ in air.

Why other options are incorrect:

- **Option A:** Steel is roughly 7850 kg/m^3 , far denser than air (1.2 kg/m^3).
- **Option B:** Air possesses an adiabatic bulk modulus that provides restoring forces for sound propagation.
- **Option D:** Sound travels as longitudinal waves in both air and the interior of isotropic solid steel.

Question #111 Key: (D)

PHYSICS
05. Waves

A block of mass [Formula] attached to an ideal horizontal spring oscillates on a frictionless s...

CORE CONCEPT & DERIVATION

In simple harmonic motion, maximum acceleration occurs at maximum displacement (amplitude), where the restoring force exerted by the spring reaches its peak.

Formula / Rule / Reaction:

$$F_{\max} = kx_0 = ma_{\max} \implies a_{\max} = \frac{k}{m}x_0 = \omega^2 x_0$$

Solution:

- Convert amplitude to meters: $x_0 = 20 \text{ cm} = 0.20 \text{ m}$.
- Given mass: $m = 10 \text{ kg}$; spring constant: $k = 20 \text{ N/m}$.
- Calculate maximum acceleration:

$$a_{\max} = \frac{20 \text{ N/m}}{10 \text{ kg}} \times 0.20 \text{ m} = 2.0 \text{ s}^{-2} \times 0.20 \text{ m} = 0.40 \text{ m/s}^2$$

Why other options are incorrect:

- **Option A:** 2.0 m/s^2 represents $\omega^2 = k/m$, omitting multiplication by amplitude.
- **Option B:** 4.0 m/s^2 is an arithmetic error.
- **Option C:** 2.2 m/s^2 incorrectly uses gravitational acceleration.

Question #112 Key: (A)

PHYSICS
05. Waves

A person with normal hearing can perceive acoustic frequencies ranging from [Formula] to [Formu...]

CORE CONCEPT & DERIVATION

Wavelength is inversely proportional to wave frequency for a constant wave speed. Maximum wavelength occurs at the minimum audible frequency.

Formula / Rule / Reaction:

$$v = f\lambda \implies \lambda_{\max} = \frac{v}{f_{\min}}$$

Solution:

- Given speed of sound: $v = 340 \text{ m/s}$.
- The lowest audible frequency is $f_{\min} = 20 \text{ Hz} = 20 \text{ s}^{-1}$.
- Calculate maximum wavelength:

$$\lambda_{\max} = \frac{340 \text{ m/s}}{20 \text{ s}^{-1}} = 17 \text{ m}$$

- The highest frequency (20 kHz) yields the minimum wavelength (17 mm).

Why other options are incorrect:

- **Option B:** 17 mm (0.017 m) corresponds to the upper frequency limit of 20 kHz.
- **Option C:** 17 cm corresponds to an intermediate frequency of 2000 Hz.
- **Option D:** 17 km corresponds to an infrasonic frequency of 0.02 Hz.

Question #113 Key: (B)

PHYSICS
13. Electronics

Crystalline sodium chloride ([Formula]) dissolves rapidly in liquid water primarily because o...

CORE CONCEPT & DERIVATION

According to Coulomb's law, the electrostatic force between two opposite charges in a dielectric medium is inversely proportional to the relative permittivity (dielectric constant) of the solvent.

Formula / Rule / Reaction:

$$F = \frac{1}{4\pi\epsilon_0\epsilon_r} \frac{|q_1q_2|}{r^2} \implies F_{\text{water}} = \frac{F_{\text{vacuum}}}{\epsilon_r} \quad (\epsilon_r \approx 80)$$

Solution:

- Water has a high dielectric constant ($\epsilon_r \approx 80$ at room temperature).
- When placed in water, the electrostatic attraction between Na^+ and Cl^- ions is reduced to roughly $1/80$ of its value in a vacuum.
- Polar water molecules hydrate the ions, releasing hydration energy that overcomes the remaining lattice energy and dissolves the crystal.

Why other options are incorrect:

- **Option A:** Low dielectric constants (e.g., in benzene) preserve strong ionic attractions, preventing ionic dissolution.
- **Option C:** Surface tension is a macroscopic property that does not govern ionic lattice breakdown.
- **Option D:** Dissolution is driven by ion-dipole hydration and dielectric screening, not Lewis acidity.

Question #114 Key: (D)

PHYSICS
08. Electrostatics

Theoretically, the time required for an ideal capacitor in an [Formula] series circuit to achie...

CORE CONCEPT & DERIVATION

Charging an ideal capacitor follows an asymptotic exponential growth function. Complete saturation theoretically requires infinite time, though practical full charge is achieved within five time constants.

Formula / Rule / Reaction:

$$q(t) = Q_0 \left(1 - e^{-t/RC}\right)$$

$$q(t) = Q_0 \iff e^{-t/RC} = 0 \implies t \rightarrow \infty$$

Solution:

- The charge $q(t)$ asymptotically approaches the maximum theoretical value $Q_0 = CV$.
- After 1τ , the capacitor reaches 63.2% charge; after 5τ , it reaches 99.3% (considered fully charged for practical engineering).
- However, true mathematical 100% charging requires the exponential decay term $e^{-t/RC}$ to reach zero, which occurs only as $t \rightarrow \infty$.

Why other options are incorrect:

- **Option A:** At $t = 1\tau$, the capacitor has accumulated only 63.2% of its maximum charge.
- **Option B:** At $t = 2\tau$, the charge reaches approximately 86.5%.
- **Option C:** Five time constants (5τ) represents practical (engineering) full charge (99.3%), not theoretical 100% completion.

Question #115 Key: (A)

 PHYSICS
08. Electrostatics

What is the magnitude of the electric field intensity at a radial distance of [Formula] from an...

CORE CONCEPT & DERIVATION

The electric field intensity due to a point charge in a vacuum is governed by Coulomb's law, varying inversely with the square of the distance from the charge.

Formula / Rule / Reaction:

$$E = \frac{1}{4\pi\epsilon_0} \frac{|q|}{r^2} = k \frac{|q|}{r^2}, \quad k = 9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2$$

Solution:

- Convert given values to SI base units:

$$q = 2.0 \mu\text{C} = 2.0 \times 10^{-6} \text{ C}, \quad r = 10 \text{ cm} = 0.10 \text{ m}$$

- Substitute into the field equation:

$$E = (9.0 \times 10^9) \frac{2.0 \times 10^{-6}}{(0.10)^2}$$

$$E = \frac{1.8 \times 10^4}{1.0 \times 10^{-2}} = 1.8 \times 10^6 \text{ N/C}$$

Why other options are incorrect:

- Option B:** $1.8 \times 10^5 \text{ N/C}$ forgets to square the radial distance in the denominator.
- Option C:** $1.8 \times 10^4 \text{ N/C}$ uses $r = 1.0 \text{ m}$ instead of 0.10 m .
- Option D:** $1.8 \times 10^3 \text{ N/C}$ is off by a factor of 10^3 .

Question #116 Key: (A)

 PHYSICS
08. Electrostatics

Two equal and opposite point charges, [Formula] and [Formula], are separated by a distance [Fo...

CORE CONCEPT & DERIVATION

Electric potential is a scalar quantity that adds algebraically, while electric field is a vector quantity that adds vectorially according to the superposition principle.

Formula / Rule / Reaction:

$$V_P = \frac{k(+q)}{d} + \frac{k(-q)}{d} = 0$$

$$\vec{E}_P = \vec{E}_+ + \vec{E}_- = \frac{k|q|}{d^2} \hat{i} + \frac{k|q|}{d^2} \hat{i} = \frac{2k|q|}{d^2} \hat{i} \neq 0$$

Solution:

- Because point P is equidistant from equal and opposite charges, the positive scalar potential cancels the negative scalar potential: $V_P = 0$.
- The electric field vector from the positive charge points away from it (to the right).
- The electric field vector from the negative charge points toward it (also to the right).
- Both field vectors point in the same direction and reinforce each other, giving a net non-zero electric field ($E \neq 0$).

Why other options are incorrect:

- Option B:** The electric field cannot be zero because both individual field vectors point in the same direction.
- Option C:** Confuses scalar potential cancellation with vector field cancellation.
- Option D:** Potential evaluates to zero due to equal and opposite charges.

Question #117 Key: (B)

 PHYSICS
07. Thermodynamics

A thermodynamic process in which all heat energy added to a closed system is used exclusively t...

CORE CONCEPT & DERIVATION

According to the First Law of Thermodynamics, heat added equals the change in internal energy plus work done. If volume remains constant, work done is zero, and all added heat increases internal energy.

Formula / Rule / Reaction:

$$\Delta Q = \Delta U + W, \quad W = P\Delta V$$

$$\Delta V = 0 \implies W = 0 \implies \Delta Q = \Delta U$$

Solution:

- In an isochoric (constant-volume) process, $\Delta V = 0$.
- The boundary of the system does not move, so no mechanical work is performed ($W = P\Delta V = 0$).
- From the First Law, $\Delta Q = \Delta U + 0 = \Delta U$.
- Therefore, 100% of the added heat energy directly increases the internal kinetic energy and temperature of the system.

Why other options are incorrect:

- Option A:** In an isobaric process, pressure is constant and added heat is split between internal energy change and expansion work ($W = P\Delta V$).
- Option C:** In an isothermal process, temperature is constant ($\Delta U = 0$), so all added heat is converted entirely into work.
- Option D:** In an adiabatic process, no heat enters or leaves the system ($\Delta Q = 0$).

Question #118 Key: (A)

 PHYSICS
12. Alternating Current

What is the phase difference between alternating voltage and alternating current in an ideal AC...

CORE CONCEPT & DERIVATION

In a capacitive AC circuit, charge accumulation depends on the integral of current over time. As a result, current reaches its maximum value one quarter-cycle before voltage reaches its peak.

Formula / Rule / Reaction:

$$V(t) = V_0 \sin(\omega t) \implies I(t) = C \frac{dV}{dt} = \omega C V_0 \cos(\omega t) = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$$

Solution:

- Applying an alternating voltage $V = V_0 \sin(\omega t)$ across a capacitor causes current to flow as $I = dq/dt$.
- Differentiating voltage yields a cosine function for current.
- Writing the cosine as a sine function reveals a phase lead of $+\frac{\pi}{2} \text{ rad } (+90^\circ)$.
- Therefore, alternating current leads voltage by $\frac{\pi}{2}$ radians.

Why other options are incorrect:

- Option B:** Voltage and current are in phase only in purely resistive circuits.
- Option C:** A phase shift of π corresponds to complete phase inversion, not capacitive reactance.
- Option D:** Current lags voltage by $\frac{\pi}{2}$ in a purely inductive circuit.

Question #119 Key: (C)

PHYSICS
08. Electrostatics

A particle carrying a net electric charge of [Formula] moves through an electric potential diff...

CORE CONCEPT & DERIVATION

The electrical work done on a charged particle accelerating through an electrostatic potential difference is converted directly into kinetic energy.

Formula / Rule / Reaction:

$$\Delta E_k = W = q\Delta V$$

Solution:

- Given charge: $q = 1.0 \text{ C}$.
- Given potential difference: $\Delta V = 5.0 \text{ V}$.
- Calculate energy gained:

$$\Delta E_k = (1.0 \text{ C}) \times (5.0 \text{ V}) = 5.0 \text{ J}$$

- The acquired kinetic energy is exactly 5.0 Joules.

Why other options are incorrect:

- Option A:** $5.0 \times 10^{-19} \text{ J}$ incorrectly uses the elementary charge $e = 1.6 \times 10^{-19} \text{ C}$ instead of 1.0 C.
- Option B:** $5.0 \times 10^{19} \text{ J}$ inverts the elementary charge exponent.
- Option D:** 0.20 J divides charge by voltage instead of multiplying.

Question #120 Key: (C)

PHYSICS
09. Current Electricity

Which of the following [Formula] characteristic curves represents a non-ohmic conductor (such a...

CORE CONCEPT & DERIVATION

Dynamic resistance is defined as $R = \frac{dV}{dI} = \frac{1}{\text{slope of } I-V \text{ graph}}$. If resistance decreases with increasing current, the slope $\frac{dI}{dV}$ must increase.

Formula / Rule / Reaction:

$$R = \frac{1}{\text{Slope}} \Rightarrow \downarrow R \Leftrightarrow \uparrow \left(\frac{dI}{dV}\right)$$

Solution:

- In an NTC thermistor or semiconductor device, thermal generation of charge carriers decreases resistance as current heats the material.
- On an I versus V plot, resistance corresponds to the reciprocal of the curve's slope.
- As resistance decreases, the slope $\frac{dI}{dV}$ becomes steeper.
- This produces an $I - V$ curve that bends upward toward the current axis.

Why other options are incorrect:

- Option A:** A straight line represents an ohmic resistor with constant resistance.
- Option B:** Bending toward the voltage axis indicates increasing resistance with current, typical of a filament lamp.
- Option D:** A horizontal line represents infinite dynamic resistance (a constant current source).

Question #121 Key: (B)

PHYSICS
09. Current Electricity

Determine the equivalent electrical resistance between terminals A and B for the circuit network...

CORE CONCEPT & DERIVATION

When n identical resistors of resistance R are connected in parallel, the equivalent resistance is reduced by a factor of n .

Formula / Rule / Reaction:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \Rightarrow R_{eq} = \frac{R}{n}$$

Solution:

- Three identical resistors, each of resistance $R = 1.0 \Omega$, are connected in parallel between nodes A and B.
- Apply the parallel combination formula:

$$\frac{1}{R_{eq}} = \frac{1}{1.0} + \frac{1}{1.0} + \frac{1}{1.0} = 3.0 \Omega^{-1}$$

- Inverting yields:

$$R_{eq} = \frac{1}{3} \Omega \approx 0.33 \Omega$$

Why other options are incorrect:

- Option A:** 3.0Ω is the equivalent resistance if the three resistors were connected in series.
- Option C:** 1.0Ω represents a single resistor branch.
- Option D:** $\frac{2}{3} \Omega$ corresponds to two resistors in parallel placed in series with another resistor.

Question #122 Key: (D)

PHYSICS
09. Current Electricity

A household operates four electric fans of [Formula] each and two lighting bulbs of [Formula] e...

CORE CONCEPT & DERIVATION

Electrical energy consumed in kilowatt-hours (kWh) is the product of total power in kilowatts and total operating time in hours.

Formula / Rule / Reaction:

$$E = P_{\text{total}}(\text{kW}) \times t(\text{hours})$$

Solution:

- Calculate total power consumption:

$$P = (4 \times 100 \text{ W}) + (2 \times 100 \text{ W}) = 400 \text{ W} + 200 \text{ W} = 600 \text{ W} = 0.60 \text{ kW}$$

- Calculate total operating hours in 30 days:

$$t_{\text{total}} = 2.0 \text{ h/day} \times 30 \text{ days} = 60 \text{ hours}$$

- Calculate total electrical energy:

$$E = 0.60 \text{ kW} \times 60 \text{ h} = 36.0 \text{ kWh}$$

Why other options are incorrect:

- Option A:** 4.0 kWh includes only the fans for a few days.
- Option B:** 12.0 kWh accounts for only 10 days of use.
- Option C:** 18.0 kWh computes energy for half of the monthly period.

Question #123 Key: (B)

PHYSICS
10. Electromagnetism

A straight wire of length [Formula] is placed perpendicular to a uniform magnetic field of [For...

CORE CONCEPT & DERIVATION

The magnetic force on a straight current-carrying conductor in a uniform magnetic field is given by the Lorentz force expression $F = ILB \sin \theta$.

Formula / Rule / Reaction:

$$F = ILB \sin \theta, \quad \theta = 90^\circ \implies \sin 90^\circ = 1$$

Solution:

- Convert length to meters: $L = 100 \text{ cm} = 1.0 \text{ m}$.
- Given current: $I = 10 \text{ A}$; magnetic flux density: $B = 0.50 \text{ T}$.
- Because the wire is perpendicular to the field, $\theta = 90^\circ$.
- Calculate magnetic force:

$$F = (10 \text{ A}) \times (1.0 \text{ m}) \times (0.50 \text{ T}) \times 1 = 5.0 \text{ N}$$

Why other options are incorrect:

- **Option A:** 50 N uses $L = 100$ without converting centimeters to meters.
- **Option C:** 10 N omits the 0.50 T factor.
- **Option D:** 0.50 N divides by current instead of multiplying.

Question #124 Key: (B)

PHYSICS
13. Electronics

Which class of materials possesses a negative temperature coefficient of electrical resistance ...

CORE CONCEPT & DERIVATION

Materials with a negative temperature coefficient of resistance show decreasing electrical resistivity as temperature rises, due to thermal excitation of charge carriers across the band gap.

Formula / Rule / Reaction:

$$R(T) = R_0[1 + \alpha(T - T_0)], \quad \alpha < 0 \implies \text{Resistance decreases as } T \text{ rises}$$

Solution:

- In intrinsic semiconductors (silicon, germanium), thermal energy promotes valence electrons across the energy gap into the conduction band.
- This produces free electrons and holes, increasing carrier density.
- The increase in charge carriers outweighs lattice scattering, lowering resistance and giving a negative temperature coefficient ($\alpha < 0$).
- In metals, higher temperature increases lattice vibrations, raising resistance ($\alpha > 0$).

Why other options are incorrect:

- **Option A:** Metallic conductors have positive temperature coefficients due to increased electron-phonon scattering.
- **Option C:** Alloys like Manganin and Constantan are designed with near-zero temperature coefficients.
- **Option D:** Superconductors have zero resistance below T_c rather than a smooth negative coefficient.

Question #125 Key: (C)

PHYSICS
08. Electrostatics

If the electric field intensity between the plates of an isolated parallel-plate capacitor is d...

CORE CONCEPT & DERIVATION

Electrostatic energy stored in a capacitor is localized within the electric field, and energy density is directly proportional to the square of the electric field intensity.

Formula / Rule / Reaction:

$$u_E = \frac{1}{2} \epsilon_0 E^2, \quad U = u_E \times \text{Volume} = \frac{1}{2} \epsilon_0 A d E^2 \implies U \propto E^2$$

Solution:

- Let the initial electric field be E_1 with energy $U_1 = kE_1^2$.
- When the electric field is doubled: $E_2 = 2E_1$.
- Calculate the new energy:

$$U_2 = k(2E_1)^2 = 4(kE_1^2) = 4U_1$$

- Therefore, the stored electrostatic energy quadruples.

Why other options are incorrect:

- **Option A:** Energy scales with E^2 , not linearly with E .
- **Option B:** Energy increases with field strength rather than decreasing.
- **Option D:** An eight-fold increase corresponds to a cubic relationship, which does not apply here.

Question #126 Key: (B)

PHYSICS
02. Force & Motion

The horizontal range of a projectile fired with initial speed [Formula] on level ground is maxi...

CORE CONCEPT & DERIVATION

The horizontal range of a projectile depends on the trigonometric term $\sin 2\theta$. Maximum range occurs when this term reaches its maximum value of 1.

Formula / Rule / Reaction:

$$R = \frac{v_0^2 \sin 2\theta}{g} \implies R = R_{\max} \iff \sin 2\theta = 1$$

Solution:

- The range formula on level ground is $R = \frac{v_0^2 \sin 2\theta}{g}$.
- Because v_0 and g are constants, R is maximized when $\sin 2\theta$ is maximized.
- The maximum value of the sine function is 1, which occurs when $2\theta = 90^\circ \implies \theta = 45^\circ$.
- Therefore, maximum range requires $\sin 2\theta = 1$.

Why other options are incorrect:

- **Option A:** $\sin \theta = 1$ occurs at $\theta = 90^\circ$ (vertical launch), producing zero horizontal range.
- **Option C:** $\sin \theta = 0$ occurs at $\theta = 0^\circ$, yielding zero range.
- **Option D:** $\sin 2\theta = 0$ gives zero horizontal range.

Question #127 Key: (C)PHYSICS
04. Rotational & Circular Motion

How many degrees of arc correspond to an angular displacement of [Formula]?

CORE CONCEPT & DERIVATIONRadians and degrees are related by π radians = 180° . Multiplying radians by $\frac{180^\circ}{\pi}$ converts the angle to degrees.

Formula / Rule / Reaction:

$$\theta(\text{degrees}) = \theta(\text{radians}) \times \left(\frac{180^\circ}{\pi}\right)$$

Solution:

- Substitute the given angle:

$$\theta = \left(\frac{2\pi}{5}\right) \times \left(\frac{180^\circ}{\pi}\right)$$

- Cancel π and evaluate:

$$\theta = \frac{2 \times 180^\circ}{5} = \frac{360^\circ}{5} = 72^\circ$$

Why other options are incorrect:

- Option A:** 36° corresponds to $\frac{\pi}{5}$ radians.
- Option B:** 50° is an arithmetic error.
- Option D:** 90° corresponds to $\frac{\pi}{2}$ radians.

Question #128 Key: (A)PHYSICS
11. Electromagnetic Induction

An ideal step-up transformer connected to a [Formula] AC supply line delivers [Formula] at an o...

CORE CONCEPT & DERIVATION

In an ideal transformer with zero power loss, the input electrical power at the primary coil equals the output power delivered by the secondary coil.

Formula / Rule / Reaction:

$$P_{\text{in}} = P_{\text{out}} \implies V_p I_p = V_s I_s \implies I_p = \frac{V_s I_s}{V_p}$$

Solution:

- Given values: primary voltage $V_p = 220$ V, secondary voltage $V_s = 1800$ V, secondary current $I_s = 22$ A.

- Calculate primary current:

$$I_p = \frac{1800 \text{ V} \times 22 \text{ A}}{220 \text{ V}} = \frac{1800}{10} = 180 \text{ A}$$

- The primary coil draws 180 A from the supply line.

Why other options are incorrect:

- Option B:** 22 A is the secondary current.
- Option C:** 50 A has no physical basis in these values.
- Option D:** 200 A is an approximate rounding error.

Question #129 Key: (B)PHYSICS
13. Electronics

In an AC-to-DC power supply circuit, which electronic component performs rectification?

CORE CONCEPT & DERIVATION

Rectification converts alternating current into unidirectional direct current. A semiconductor pn-junction diode allows current flow in the forward-biased direction while blocking reverse current.

Formula / Rule / Reaction:

$$\text{Forward Bias } (V > V_{\text{th}}) \implies \text{Conducts, Reverse Bias } (V < 0) \implies \text{Blocks}$$

Solution:

- A transformer modifies AC voltage magnitude, but the output remains alternating current.
- A semiconductor diode conducts during forward half-cycles and blocks during reverse half-cycles.
- This unidirectional conduction converts AC waveforms into pulsating DC.

Why other options are incorrect:

- Option A:** A transformer changes AC voltage amplitude, but does not rectify AC to DC.
- Option C:** A capacitor filters and smooths voltage ripple after rectification.
- Option D:** A Zener diode operates in reverse breakdown to regulate voltage, not for primary rectification.

Question #130 Key: (D)PHYSICS
16. Nuclear Physics

The positron emission decay of radioactive fluorine-18 is represented by the nuclear reaction: ...

CORE CONCEPT & DERIVATIONIn beta-plus (β^+) decay, a proton within an unstable nucleus transforms into a neutron, emitting a positron and an electron neutrino to conserve charge and lepton number.

Formula / Rule / Reaction:

$$p \longrightarrow n + e^+ + \nu_e$$

$${}_{9}^{18}\text{F} \longrightarrow {}_{8}^{18}\text{O} + {}_{+1}^{0}\text{e} + {}_{0}^{0}\nu_e \quad (\text{positron}) + (\text{neutrino})$$

Solution:

- Conserve mass number: $A = 18 = 18 + 0 + 0$.
- Conserve atomic number (charge): $Z = 9 = 8 + (+1) + 0$. Particle x carries +1 charge, identifying it as a positron (e^+).
- To conserve lepton family number ($L = 0 \longrightarrow -1 + L_y$), particle y must carry $L = +1$, identifying it as an electron neutrino (ν_e).

Why other options are incorrect:

- Option A:** Alpha emission would decrease the mass number by 4 to 14.
- Option B:** Beta-minus decay would increase atomic number to 10 (neon), not 8.
- Option C:** Neutron emission would lower mass number to 17 without changing atomic number.

Question #131 Key: (B)PHYSICS
16. Nuclear Physics

One roentgen equivalent man (rem) is related to the gray (Gy) and relative biological effective...

CORE CONCEPT & DERIVATION

Equivalent dose quantifies biological radiation damage by scaling the absorbed physical dose by the relative biological effectiveness (RBE) of the radiation type.

Formula / Rule / Reaction:

$$\text{Dose in rem} = \text{Dose in rad} \times \text{RBE}$$

$$1 \text{ rad} = 0.01 \text{ Gy} \implies 1 \text{ rem} = 0.01 \text{ Gy} \times \text{RBE}$$

Solution:

- The historical unit of equivalent dose is the rem.
- By definition, Dose equivalent (rem) = Absorbed dose (rad) $\times$ RBE.
- Since $1 \text{ Gy} = 100 \text{ rad}$, it follows that $1 \text{ rad} = 0.01 \text{ Gy}$.
- Substituting gives $1 \text{ rem} = 0.01 \text{ Gy} \times \text{RBE}$.

Why other options are incorrect:

- Option A:** Inverts the RBE term into the denominator.
- Option C:** Lacks the physical absorbed dose unit.
- Option D:** $1.0 \text{ Gy} \times \text{RBE}$ defines the modern SI unit sievert (Sv), where $1 \text{ Sv} = 100 \text{ rem}$.

Question #132 Key: (A)PHYSICS
16. Nuclear Physics

One radiation absorbed dose (rad) corresponds to an energy absorption per unit mass of biologic...

CORE CONCEPT & DERIVATION

Absorbed dose measures ionizing radiation energy deposited per unit mass of absorbing material.

Formula / Rule / Reaction:

$$1 \text{ rad} = 100 \text{ ergs/g} = 10^{-2} \text{ J/kg} = 0.01 \text{ J/kg} = 0.01 \text{ Gy}$$

Solution:

- In cgs units, 1 rad is defined as 100 ergs of energy absorbed per gram of tissue.
- Convert to SI units:

$$100 \text{ ergs} = 100 \times 10^{-7} \text{ J} = 10^{-5} \text{ J}$$

$$1 \text{ g} = 10^{-3} \text{ kg}$$

$$\frac{10^{-5} \text{ J}}{10^{-3} \text{ kg}} = 10^{-2} \text{ J/kg} = 0.01 \text{ J/kg}$$

Why other options are incorrect:

- Option B:** $0.01 \text{ kJ/g} = 10 \text{ J/g} = 10^4 \text{ J/kg}$, which is off by six orders of magnitude.
- Option C:** Energy alone lacks the unit mass denominator required for absorbed dose.
- Option D:** 1.0 J/kg defines the SI unit gray ($1 \text{ Gy} = 100 \text{ rad}$).

Question #133 Key: (C)PHYSICS
16. Nuclear Physics

A [Formula] individual receives a whole-body equivalent dose of [Formula] from radiation having...

CORE CONCEPT & DERIVATION

Physical energy absorbed depends on the absorbed dose, which is obtained by dividing the equivalent dose by the RBE factor.

Formula / Rule / Reaction:

$$D(\text{rad}) = \frac{H(\text{rem})}{\text{RBE}}, \quad D(\text{Gy}) = D(\text{rad}) \times 0.01 \text{ J/kg}$$

$$E_{\text{absorbed}} = D(\text{Gy}) \times m(\text{kg})$$

Solution:

- Calculate absorbed dose in rad:

$$D = \frac{200 \text{ rem}}{10} = 20 \text{ rad}$$

- Convert absorbed dose to grays (J/kg):

$$D = 20 \times 0.01 \text{ J/kg} = 0.20 \text{ J/kg}$$

- Calculate total absorbed energy across 60 kg:

$$E = 0.20 \text{ J/kg} \times 60 \text{ kg} = 12.0 \text{ J}$$

Why other options are incorrect:

- Option A:** 9.0 J is an arithmetic error.
- Option B:** 8.0 J uses an incorrect mass or dose value.
- Option D:** 120 J fails to divide by the RBE factor of 10.

Question #134 Key: (C)PHYSICS
16. Nuclear Physics

Which of the following biological consequences is classified strictly as a somatic effect of io...

CORE CONCEPT & DERIVATION

Somatic radiation effects occur directly in the body tissues of the irradiated individual, whereas genetic (hereditary) effects result from mutations in germline cells that affect subsequent generations.

Formula / Rule / Reaction:

Factual recall / Radiation Biology:

Solution:

- Somatic effects include radiation dermatitis, skin burns, cataracts, bone marrow depression, and carcinogenesis in the exposed person.
- Because skin burns and erythema occur directly on the body of the exposed individual, they are somatic effects.
- Mutations in germ cells (spermatocytes or oocytes) that produce inherited defects in offspring are classified as genetic effects.

Why other options are incorrect:

- Option A:** Germline DNA alterations are genetic effects passed to offspring.
- Option B:** Malformations in offspring are hereditary effects, not somatic effects.
- Option D:** Chromosomal aberrations in gametes are genetic effects.

Question #135 Key: (A)PHYSICS
16. Nuclear Physics

On average, a human being receives an annual natural background radiation equivalent dose of ap...

CORE CONCEPT & DERIVATION

Natural background radiation arises from cosmic rays, terrestrial radionuclides (radon gas in rocks), and internal radioisotopes like potassium-40.

Formula / Rule / Reaction:

Factual recall / Environmental Physics.

Solution:

- Worldwide average natural background radiation exposure is approximately 1.0 to 2.4 mSv per year.
- Radon gas inhalation typically contributes about half of this dose.
- Cosmic rays, soil minerals, and dietary sources contribute the remainder.

Why other options are incorrect:

- Option B:** 20 mSv is the occupational annual dose limit for radiation workers.
- Option C:** 100 mSv is the lowest cumulative threshold associated with statistically detectable increases in cancer risk.
- Option D:** 1.0 Sv (1000 mSv) causes acute radiation sickness.

Question #136 Key: (B)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Identify the grammatical function of the underlined modal in the sentence below: "The commercia...

CORE CONCEPT & DERIVATION

Modal auxiliaries express modality such as obligation, expectation, probability, or necessity. They precede the base form of a main verb and lack inflected forms.

Formula / Rule / Reaction:

Subject + Modal Auxiliary (ought to) + Bare Infinitive (be) + ...

Solution:

- "Ought to" is a semi-modal auxiliary verb that expresses strong expectation or moral obligation.
- It modifies the primary verb phrase "be landing" without changing form for person or number.
- Therefore, it functions as a modal auxiliary.

Why other options are incorrect:

- Option A:** Linking verbs (e.g., seem, appear, become) connect a subject to a subject complement.
- Option C:** A phrasal verb combines a verb and a particle (e.g., take off, give up) to create a new idiomatic meaning.
- Option D:** Transitive verbs require a direct object to complete their meaning.

Question #137 Key: (D)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

In the sentence, "During the heavy rainstorm, the afternoon sky grew dark," the underlined verb...

CORE CONCEPT & DERIVATION

A linking (copular) verb connects the subject of a clause to a subject complement (an adjective or noun) that describes or identifies the subject, rather than expressing an action.

Formula / Rule / Reaction:

Subject (the sky) + Linking Verb (grew) + Predicate Adjective (dark)

Solution:

- The verb "grew" indicates a change of state rather than physical action.
- It links the subject noun phrase ("the afternoon sky") to the predicate adjective ("dark").
- Because "dark" describes the condition of the subject, "grew" functions as a linking verb.

Why other options are incorrect:

- Option A:** "Grew" is a finite verb marked for past tense.
- Option B:** Transitive verbs require a direct object; "dark" is an adjective complement, not an object.
- Option C:** While linking verbs are intransitive in taking no object, "grew" acts copularly to link an adjective rather than expressing an action.

Question #138 Key: (B)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

In the sentence, "His exceptional courage brought him honour," the underlined verb is classifi...

CORE CONCEPT & DERIVATION

A ditransitive verb takes two objects: an indirect object (the recipient) and a direct object (the thing acted upon or transferred).

Formula / Rule / Reaction:

Subject + Ditransitive Verb + Indirect Object (IO) + Direct Object (DO)

Solution:

- The subject is "His exceptional courage".
- The verb "brought" governs two noun phrases: "him" and "honour".
- "Honour" is the direct object receiving the action, while "him" is the indirect object recipient.
- Verbs that take both an indirect and a direct object are ditransitive.

Why other options are incorrect:

- Option A:** Intransitive verbs take no objects.
- Option C:** Complex transitive verbs take a direct object and an object complement (e.g., "They elected him president").
- Option D:** Copular verbs link subjects to subject complements.

Question #139 Key: (B)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

In the sentence, "The teacher assigned the students an assignment to be completed during vacati...

CORE CONCEPT & DERIVATION

A ditransitive verb licenses both an indirect object (the beneficiary) and a direct object (the transferred entity).

Formula / Rule / Reaction:

Subject (The teacher) + Verb (assigned) + IO (the students) + DO (an assignment)

Solution:

- "The students" functions as the indirect object.
- "An assignment" functions as the direct object.
- Because "assigned" takes two objects, it is a ditransitive verb.

Why other options are incorrect:

- **Option A:** Monotransitive verbs take only a single direct object.
- **Option C:** Complex transitive verbs require an object complement describing the direct object.
- **Option D:** Intransitive verbs do not take objects.

Question #140 Key: (A)ENGLISH
03. Parts of Speech, Prepositions & Modifiers

In the traditional proverb, "Of two evils choose the less," the underlined word functions as a...

CORE CONCEPT & DERIVATION

The irregular adjective "little" inflects as "little" (positive), "less" or "lesser" (comparative), and "least" (superlative). The comparative degree is used when comparing two items.

Formula / Rule / Reaction:

Degrees of Comparison: Little (Positive) → Less / Lesser (Comparative) → Least (Superlative)

Solution:

- The sentence compares two alternatives ("Of two evils").
- Comparing two items requires the comparative degree.
- = "less" is the comparative form of "little".
- Here, "less" functions as an adjective used substantively to denote the lesser of two evils.

Why other options are incorrect:

- **Option B:** The positive degree is "little".
- **Option C:** The superlative degree is "least" (used for three or more items).
- **Option D:** Distributive adjectives include words like "each", "every", "either", and "neither".

Question #141 Key: (A)ENGLISH
03. Parts of Speech, Prepositions & Modifiers

In the interrogative sentence, "Are there any mango trees in this garden?", the underlined word...

CORE CONCEPT & DERIVATION

Indefinite determiners and adjectives of quantity modify nouns by indicating an unspecified amount or number, typically in questions and negative statements.

Formula / Rule / Reaction:

Determiner / Quantitative Adjective (any) + Plural Countable Noun (mango trees)

Solution:

- The word "any" modifies the noun "mango trees".
- It specifies an indefinite number or quantity in a question.
- Therefore, it functions as an indefinite adjective of quantity / quantifying determiner.

Why other options are incorrect:

- **Option B:** Adjectives of quality describe inherent attributes (e.g., sweet, green, tall).
- **Option C:** Relative pronouns (e.g., which, that, who) introduce relative clauses.
- **Option D:** Reciprocal pronouns are phrases like "each other" and "one another".

Question #142 Key: (B)ENGLISH
03. Parts of Speech, Prepositions & Modifiers

In the sentence, "This is the very thing we want," the underlined word functions as an:

CORE CONCEPT & DERIVATION

When the word "very" directly precedes and modifies a noun, it functions as an emphasizing adjective meaning "exact" or "particular".

Formula / Rule / Reaction:

Definite Article (the) + Emphasizing Adjective (very) + Noun (thing)

Solution:

- "Very" modifies the noun "thing", emphasizing its precise identity.
- Because it modifies a noun rather than an adjective or adverb, it functions as an adjective.
- In this context, it is categorized as an emphasizing adjective.

Why other options are incorrect:

- **Option A:** Emphatic pronouns end in -self/-selves (e.g., himself, themselves) and follow nouns for emphasis.
- **Option C:** Reflexive pronouns indicate that the subject and object are the same person or thing.
- **Option D:** "Very" modifies a noun here, not a verb or adjective.

Question #143 Key: (B)ENGLISH
03. Parts of Speech, Prepositions & Modifiers

In the warning, "Don't be in such a hurry," the underlined word is used as an adjective of:

CORE CONCEPT & DERIVATION

The word "such" acts as a demonstrative/degree adjective or pre-determiner when modifying a noun phrase, emphasizing degree, manner, or extent.

Formula / Rule / Reaction:

Pre-determiner / Degree Adjective (such) + a + Noun (hurry)

Solution:

- "Such" modifies the singular count noun "hurry".
- It emphasizes the degree or intensity of haste.
- Therefore, it functions as an emphasizing/degree determiner.

Why other options are incorrect:

- **Option A:** Adjectives of definite number specify exact counts (e.g., one, two).
- **Option C:** Distributive adjectives refer to items individually (e.g., each, every).
- **Option D:** Interrogative adjectives ask questions (e.g., which, what).

Question #144 Key: (D)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Fill in the blank with the appropriate verb form indicating the Past Perfect Continuous tense: ...

CORE CONCEPT & DERIVATION

The past perfect continuous tense denotes an ongoing action that began in the past and continued up until another reference point in the past.

Formula / Rule / Reaction:

Subject + had been + Present Participle (verb-ing) + ...

Solution:

- The past perfect continuous requires the auxiliary "had been" followed by the "-ing" present participle.
- The option matching this structure is "had been walking".
- This describes an ongoing habit prior to another past reference event.

Why other options are incorrect:

- **Option A:** "Had walked" is the past perfect simple tense.
- **Option B:** "Has been walking" is the present perfect continuous tense.
- **Option C:** "Walked" is the simple past tense.

Question #145 Key: (A)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

"All desire wealth, and some acquire it," This compound sentence exemplifies which grammatical ...

CORE CONCEPT & DERIVATION

The present indefinite tense uses the base form of the verb to express general truths, universal facts, or habitual actions.

Formula / Rule / Reaction:

Clause 1: All + desire (base form), Clause 2: some + acquire (base form)

Solution:

- The verb in the first clause is "desire".
- The verb in the second clause is "acquire".
- Both are simple present finite verb forms without auxiliaries, stating a general observation about human behavior.
- Therefore, the sentence is in the present indefinite tense.

Why other options are incorrect:

- **Option B:** Past indefinite forms would be "desired" and "acquired".
- **Option C:** Present perfect would require "have desired" and "have acquired".
- **Option D:** Simple future would require "will desire" and "will acquire".

Question #146 Key: (B)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Identify the sentence that contains an INCORRECT grammatical structure:

CORE CONCEPT & DERIVATION

In inverted sentences starting with prepositional phrases, the verb must agree in number with the compound subject that follows it.

Formula / Rule / Reaction:

In him [were (plural)] centered [piety and wisdom (compound plural subject)]

Solution:

- In Option B, the subject is the compound noun phrase "piety and wisdom" joined by "and".
- A compound subject requires a plural verb: "were centered", not the singular "was centered".
- Therefore, Option B contains an agreement error.

Why other options are incorrect:

- **Option A:** When a subject is joined with phrases like "as well as", the verb agrees with the first subject ("Justice" → "allows").
- **Option C:** "The wages of sin is death" is an established singular construction where "wages" functions as an abstract singular noun.
- **Option D:** "Fire and water" is a compound subject correctly taking the plural auxiliary "do not agree".

Question #147 **Key: (B)**ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals*"If I were a doctor, I would serve humanity." This sentence is an example of which type of cond...***CORE CONCEPT & DERIVATION**

A Type II (second) conditional expresses an unreal, hypothetical, or contrary-to-fact situation in the present or future, using the subjunctive past in the if-clause and modal would + base verb in the main clause.

Formula / Rule / Reaction:

If + Subject + were / past subjunctive, Subject + would + base verb

Solution:

- The conditional clause uses the subjunctive form "were" ("If I were a doctor").
- The main result clause uses "would serve".
- This structure indicates a hypothetical present condition and its imagined result, defining a Type II conditional.

Why other options are incorrect:

- **Option A:** Zero conditionals use simple present in both clauses to express scientific facts (e.g., "If you heat ice, it melts").
- **Option C:** Type I conditionals use simple present and simple future for real possibilities (e.g., "If I study, I will pass").
- **Option D:** Type III conditionals use past perfect and would have + past participle for past unreal situations (e.g., "If I had known, I would have acted").

Question #148 **Key: (A)**ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals*Choose the sentence that is grammatically and conditionally structured correctly:***CORE CONCEPT & DERIVATION**

A third conditional expresses an unfulfilled situation in the past and requires past perfect in the subordinate if-clause paired with a modal perfect (would have + past participle) in the main clause.

Formula / Rule / Reaction:

If + Subject + had + V₃, Subject + would have + V₃

Solution:

- The condition is introduced with past perfect: "If we had found him earlier".
- The main clause correctly completes the third conditional with "we would have saved his life".
- Both clauses maintain correct past unfulfilled tense agreement.

Why other options are incorrect:

- **Option B:** "would saved" is missing the auxiliary "have" after "would".
- **Option C:** "will have saved" incorrectly pairs past perfect with a future perfect main clause.
- **Option D:** Mixes a simple past if-clause ("found") with a third conditional main clause ("would have saved").

Question #149 **Key: (B)**ENGLISH
05. Active-Passive Voice, Reported Speech & Syntax*"Owing to his bad luck, he got into an accident on the eve of his examination." What structural...***CORE CONCEPT & DERIVATION**

A simple sentence contains exactly one independent clause (one subject-predicate finite core) and no dependent (subordinate) clauses, regardless of modifying phrases.

Formula / Rule / Reaction:

Prepositional Phrase + [Subject (he) + Finite Verb (got) + ... (Single Independent Clause)]

Solution:

- "Owing to his bad luck" is a prepositional/participial phrase functioning as an adverbial modifier; it lacks a subject and finite verb, so it is not a clause.
- The remainder of the sentence, "he got into an accident on the eve of his examination", contains a single subject ("he") and finite verb ("got").
- Because there is only one independent clause and zero subordinate clauses, the sentence is a simple sentence.

Why other options are incorrect:

- **Option A:** A complex sentence requires at least one independent clause and at least one dependent (subordinate) clause.
- **Option C:** A compound sentence requires at least two independent clauses joined by a coordinating conjunction or semicolon.
- **Option D:** A compound-complex sentence requires at least two independent clauses and one or more dependent clauses.

Question #150 **Key: (C)**ENGLISH
06. Punctuation, Capitalization & Reading Comprehension*Which of the following sentences exhibits correct punctuation and possessive apostrophe placement...***CORE CONCEPT & DERIVATION**

Plural nouns ending in -s form their possessive with an apostrophe after the s (siblings'). Restrictive and non-restrictive relative clauses must be properly set off with commas.

Formula / Rule / Reaction:

Plural Possessive: siblings+' = siblings' | Non-restrictive relative: , whose ...

Solution:

- "Siblings'" correctly uses a plural possessive apostrophe to indicate bags belonging to multiple siblings.
- "Chief of the boys" uses a clear, grammatical prepositional phrase rather than the awkward "boys chief".
- The non-restrictive relative clause ", whose gun was black" is set off with a comma.
- Therefore, Option C is correctly punctuated.

Why other options are incorrect:

- **Option A:** Omits the possessive apostrophe in "siblings" and lacks a comma before "whose".
- **Option B:** Lacks the possessive apostrophe in "siblings" and uses the awkward "boys chief".
- **Option D:** Omits the possessive apostrophe on "siblings".