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NUMS RAWALPINDI

NUMS 2022 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-2022 Duration: 150 Minutes (2h 30m)

150

TOTAL QUESTIONS

150m

OFFICIAL DURATION

+1 / 0.00

ZERO NEGATIVE MARKING

150

MAXIMUM MARKS

EXAMINATION BLUEPRINT & SUBJECT WEIGHTAGE

Biology**55 MCQs**

36.7% weight

Physics**40 MCQs**

26.7% weight

English**15 MCQs**

10.0% weight

Chemistry**40 MCQs**

26.7% weight

BIO SECTION: BIOLOGY

Questions 1 to 55 (55 MCQs)

Q1. BIO

Which organelle would be more abundant in a secretory cell than in a non-secretory cell?

- (A) Lysosome
- (B) Golgi complex
- (C) Centriole
- (D) Vacuole

Q2. BIO

The structure which disappears during cell division is the:

- (A) Vacuole
- (B) Lysosome
- (C) Nucleus
- (D) Endoplasmic reticulum

Q3. BIO

The enzyme ATP synthase is located on the membrane of which organelle?

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

Q4. BIO

Spherical sacs surrounded by a single membrane and containing hydrolytic enzymes are called:

- (A) Mitochondria
- (B) Golgi bodies
- (C) Chloroplasts
- (D) Lysosomes

Q5. BIO

Except during nuclear division, the nucleus contains chromosomes in a loosely coiled, dispersed state known as:

- (A) Genes
- (B) Ribosomes
- (C) Chromatin
- (D) Histones

Q6. BIO

Within the nucleus, ribosomal subunits are assembled by the:

- (A) Nucleolus
- (B) Nuclear envelope
- (C) Endoplasmic reticulum
- (D) Kinetochore

Q7. BIO

Which of the following descriptions is correct for the plant cell wall?

- (A) Semi-permeable
- (B) Differentially permeable
- (C) Fully permeable
- (D) Completely impermeable

Q8. BIO

Why is the plasma membrane described as asymmetrical?

- (A) Proteins are completely static in position
- (B) Hydrophobic tails face inward while hydrophilic heads face outward
- (C) Cholesterol molecules are restricted exclusively to the cytosolic face
- (D) The two surfaces and lipid leaflets are not identical in composition

Q9. BIO

The cell membrane contains which structures through which the transport of materials takes place by active and passive mechanisms?

- (A) Charged pores
- (B) Phospholipid tails
- (C) Cholesterol plaques
- (D) Glycocalyx networks

Q10. BIO

Which biochemical component of the plasma membrane primarily regulates membrane fluidity?

- (A) Glycoprotein
- (B) Lipid
- (C) Carrier protein
- (D) Carbohydrate

Q11. BIO

A group of ribosomes attached to a single mRNA molecule is known as a polysome. This ribosomal attachment is controlled by the concentration of:

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

Q12. BIO

An automatic, involuntary, and rapid response to any external or internal stimulus is called a:

- (A) Reflex
- (B) Instinct
- (C) Taxis
- (D) Tropism

Q13. BIO

The resting membrane potential of a typical human neuron measures approximately:

- (A) -70 mV
- (B) -70 V
- (C) $+70 \text{ mV}$
- (D) -90 mV

Q14. BIO

Sensory receptors specialized for detecting light, discriminative touch in hairless skin are:

- (A) Pacinian corpuscles
- (B) Olfactory receptors
- (C) Meissner corpuscles
- (D) Nociceptors

Q15. BIO

Which of the following processes is NOT a physiological function of the human large intestine?

- (A) Absorption of electrolytes
- (B) Absorption of water
- (C) Production of vitamins
- (D) Absorption of amino acids

Q16. BIO

Which anatomical passageway is shared by both the digestive and respiratory systems in human beings?

- (A) Trachea
- (B) Pharynx
- (C) Larynx
- (D) Oesophagus

Q17. BIO

In a healthy human heart, the rhythmic electrical impulses are initiated and regulated by the:

- (A) Purkinje fibers
- (B) Atrioventricular bundle
- (C) Sinoatrial node
- (D) Bundle of His

Q18. BIO

Which method helps develop active, long-lasting immunity against pathogenic bacteria?

- (A) Radiotherapy
- (B) Chemotherapy
- (C) Antibiotic therapy
- (D) Vaccination

Q19. BIO

The normal gestation period in human beings is approximately:

- (A) 240 to 250 days
- (B) 270 to 280 days
- (C) 300 to 320 days
- (D) 322 to 350 days

Q20. BIO

During the human menstrual cycle, after ovulation releases the secondary oocyte, the remaining follicular tissue transforms into a temporary endocrine gland that primarily secretes:

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

Q21. BIO

In the male reproductive system, the hormone that exerts negative feedback to regulate the rate of spermatogenesis is:

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

Q22. BIO

The cervix is an anatomical division of the:

- (A) Vagina
- (B) Oviduct
- (C) Uterus
- (D) Ovary

Q23. BIO

Which type of cartilage is the most abundant in the human body?

- (A) Fibrocartilage
- (B) Hyaline cartilage
- (C) Elastic cartilage
- (D) Calcified cartilage

Q24. BIO

Which of the following is an example of an immovable fibrous joint known as a suture?

- (A) Cranial bones
- (B) Intervertebral disc
- (C) Costal cartilage
- (D) Pubic symphysis

Q25. BIO

Which event does NOT occur during skeletal muscle contraction?

- (A) I-band shortens
- (B) A-band shortens
- (C) H-zone disappears
- (D) Z-lines move closer together

Q26. BIO

Smooth muscle cells are spindle-shaped, non-striated, and typically possess how many nuclei per cell?

- (A) One
- (B) Two
- (C) Three
- (D) Many

Q27. BIO

Which human ABO and Rh blood type is designated as the universal red blood cell donor?

- (A) A⁺
- (B) O⁻ coordinator
- (C) AB⁺
- (D) O⁺

Q28. BIO

Which of the following characteristics of a virus represents a living characteristic?

- (A) Capability of being crystallized
- (B) Absence of cellular respiration
- (C) Ability to undergo genetic mutation
- (D) Lack of independent biosynthetic machinery

Q29. BIO

A group of natural populations whose individuals possess similar morphological and physiological traits and can interbreed to produce fertile offspring is defined as a:

- (A) Species
- (B) Genus
- (C) Family
- (D) Order

Q30. BIO

Under aerobic conditions, the complete oxidation of one molecule of glucose in prokaryotic cells yields a net total of how many ATP molecules?

- (A) 32
- (B) 36
- (C) 38
- (D) 40

Q31. BIO

What are the primary chemical products generated by the light-dependent reactions of photosynthesis?

- (A) ATP, RuBP, and reduced NAD
- (B) GP, oxygen, and reduced NAD
- (C) GP, reduced NADP, and RuBP
- (D) ATP, oxygen, and reduced NADP

Q32. BIO

During the process of oxygenic photosynthesis, water molecules act as:

- (A) Proton acceptors
- (B) Electron donors
- (C) Carbon dioxide reducers
- (D) Carbon dioxide acceptors

Q33. BIO

During photosynthetic carbon fixation in the Calvin cycle, carbon dioxide functionally acts as a:

- (A) Proton donor
- (B) Electron donor
- (C) Proton acceptor
- (D) Source of oxygen gas

Q34. BIO

The direct three-carbon carbohydrate end product synthesized and exported by the Calvin cycle is:

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

Q35. BIO

Which of the following biomolecules is composed of amino acids?

- (A) Cellulose
- (B) Collagen
- (C) Sucrose
- (D) Ascorbic acid

Q36. BIO

Hydrolysis is the chemical breakdown of a polymer into its constituent monomers through the addition of:

- (A) Hydroxyl groups
- (B) Hydrogen atoms
- (C) Water molecules
- (D) Nitrogen groups

Q37. BIO

Which of the following organic compounds is NOT classified as a carbohydrate?

- (A) Glucose ($C_6H_{12}O_6$)
- (B) Sucrose ($C_{12}H_{22}O_{11}$)
- (C) Rhamnose ($C_6H_{12}O_5$)
- (D) Lactic acid ($C_3H_6O_3$)

Q38. BIO

Owing to its high latent heat of vaporization, water plays an essential physiological role in living organisms as a:

- (A) Universal solvent
- (B) Evaporative cooling agent
- (C) Membrane stabilizer
- (D) Thermal insulator

Q39. BIO

Which of the following biological molecules does NOT contribute to the structural framework of biological membranes?

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

Q40. BIO

Which of the following disaccharide molecules yields both D-glucose and D-fructose upon complete enzymatic or acid hydrolysis?

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

Q41. BIO

The specialized repetitive DNA sequences capping the terminal ends of eukaryotic chromosomes are called:

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

Q42. BIO

The narrow fluid-filled extracellular space separating the presynaptic terminal from the postsynaptic membrane at a chemical synapse is the:

- (A) Synaptic knob
- (B) Synaptic cleft
- (C) Synaptic delay
- (D) Synaptic vesicle

Q43. BIO

The neuroanatomical structure that functions as the central homeostatic thermostat regulating core body temperature in human beings is the:

- (A) Thalamus
- (B) Hypothalamus
- (C) Pons
- (D) Cerebellum

Q44. BIO

A long, slender cytoplasmic extension that propagates nerve impulses away from the neuronal cell body is called an:

- (A) Axon
- (B) Auxin
- (C) Schwann cell
- (D) Dendrite

Q45. BIO

Which of the following endocrine signaling molecules is classified chemically as a steroid hormone?

- (A) Cortisone
- (B) Adrenaline
- (C) Insulin
- (D) Thyroxine

Q46. BIO

Endogenous chemical messengers released at synaptic junctions to transmit signals from one neuron to another or to an effector cell are called:

- (A) Hormones
- (B) Activators
- (C) Neurotransmitters
- (D) Enzymes

Q47. BIO

Which of the following digestive enzymes exhibits an alkaline optimum pH for its catalytic activity?

- (A) Pepsin
- (B) Salivary amylase
- (C) Enterokinase
- (D) Pancreatic lipase

Q48. BIO

In the study of enzyme kinetics, the term 'minimum temperature' refers to the temperature at which:

- (A) Enzymes undergo irreversible thermal denaturation
- (B) Enzymes reach their maximum catalytic velocity
- (C) Enzymes become completely hyperactive
- (D) An inactive enzyme begins to regain measurable catalytic activity

Q49. BIO

Which of the following statements correctly describes non-competitive enzyme inhibition?

- (A) The inhibitor competes directly with the substrate for the catalytic active site
- (B) The inhibitor binds to an allosteric site, altering enzyme conformation
- (C) Malonate acts as the primary classic model inhibitor
- (D) The inhibitory effect can be reversed simply by increasing substrate concentration

Q50. BIO

Which type of digestive enzyme would show the highest catalytic activity in your gut immediately after consuming a starch-rich loaf of bread?

- (A) Amylase
- (B) Erepsin
- (C) Lactase
- (D) Carboxypeptidase

Q51. BIO

The foundational evolutionary treatise titled 'On the Origin of Species by Means of Natural Selection' was presented by:

- (A) Lamarck
- (B) Linnaeus
- (C) Hardy-Weinberg
- (D) Darwin

Q52. BIO

Which of the following is NOT a direct immunological mechanism of action carried out by circulating antibodies?

- (A) Neutralization of toxins and viral particles
- (B) Precipitation of soluble antigens
- (C) Direct secretion of cytokines
- (D) Opsonization enhancing phagocytosis

Q53. BIO

Magnesium is an essential mineral nutrient in green plants primarily required for the biosynthesis of:

- (A) Proteins
- (B) Lipids
- (C) Chlorophylls
- (D) Enzymes

Q54. BIO

Which of the following anatomical divisions of the human respiratory tract completely lacks supportive cartilage in its walls?

- (A) Larynx
- (B) Trachea
- (C) Bronchioles
- (D) Bronchi

Q55. BIO

The enzymatic portion of gastric juice, containing the proenzyme pepsinogen, is secreted by which mucosal cells of the stomach?

- (A) Oxyntic cells
- (B) Chief cells
- (C) Mucous neck cells
- (D) Enteroendocrine cells

PHY SECTION: PHYSICS

Questions 56 to 95 (40 MCQs)

Q56. PHY

The horizontal distance traversed by a periodic wave during the time required to complete one full cycle of oscillation is the:

- (A) Frequency
- (B) Wavelength
- (C) Amplitude
- (D) Time period

Q57. PHY

If the period of oscillation of a mass M suspended from an ideal spring is 2 s, what will be the period of oscillation if the suspended mass is increased to $4M$?

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

Q58. PHY

The psychological perception of the loudness of a sound wave is most directly related to which physical wave property?

- (A) Intensity of sound
- (B) Frequency of sound
- (C) Wavelength of sound
- (D) Speed of sound

Q59. PHY

The increase in the speed of sound in dry air for each degree Celsius rise in temperature above 0°C is approximately:

- (A) 0.40 m s^{-1}
- (B) 0.51 m s^{-1}
- (C) 0.81 m s^{-1}
- (D) 0.61 m s^{-1}

Q60. PHY

The first law of thermodynamics is a direct mathematical manifestation of the fundamental law of conservation of:

- (A) Charge
- (B) Mass
- (C) Linear momentum
- (D) Energy

Q61. PHY

A thermodynamic process in which the pressure of the working gas remains constant throughout the expansion or compression is called an:

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

Q62. PHY

The electrostatic potential energy stored in a charged parallel plate capacitor of capacitance C across potential difference V is given by:

- (A) $E = \frac{1}{2}CV^2$
- (B) $E = 2CV^2$
- (C) $E = CV^2$
- (D) $E = \frac{1}{2}C^2V$

Q63. PHY

Electric field intensity at a given point in space is defined physically as the:

- (A) Force experienced per unit mass
- (B) Force experienced per unit magnetic pole
- (C) Force experienced per unit positive test charge
- (D) Work done per unit charge

Q64. PHY

Which of the following electronic components stores energy predominantly in the form of an electrostatic potential field?

- (A) Capacitor
- (B) Conductor
- (C) Inductor
- (D) Generator

Q65. PHY

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

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

Q66. PHY

The electrical resistance of a pure metallic conductor increases with an:

- (A) Increase in temperature
- (B) Increase in pressure
- (C) Decrease in temperature
- (D) Decrease in pressure

Q67. PHY

The magnetic field intensity B at a radial distance r inside a long, straight cylindrical wire carrying a uniformly distributed steady current varies:

- (A) Inversely with r
- (B) Inversely with r^2
- (C) Directly with r^2
- (D) Directly with r

Q68. PHY

The magnetic flux passing through a plane surface of area vector $\mathbf{A}$ immersed in a uniform magnetic field $\mathbf{B}$ is maximum when the angle between $\mathbf{B}$ and $\mathbf{A}$ is:

- (A) 0°
- (B) 90°
- (C) 45°
- (D) 180°

Q69. PHY

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

- (A) Mass
- (B) Energy
- (C) Charge
- (D) Momentum

Q70. PHY

In Fleming's right-hand generator rule, the thumb points in the direction of the:

- (A) Motion of the conductor
- (B) Magnetic field
- (C) Induced current
- (D) Electric field

Q71. PHY

An electrical transformer operates on the physical principle of:

- (A) Half-wave rectification
- (B) Self-induction
- (C) Mutual induction
- (D) Full-wave rectification

Q72. PHY

A semiconductor electronic device primarily used to convert alternating current (AC) into direct current (DC) is called a:

- (A) Rectifier
- (B) Transistor
- (C) Capacitor
- (D) Inductor

Q73. PHY

The electrical process of converting alternating current (AC) into unidirectional direct current (DC) is known as:

- (A) Amplification
- (B) Rectification
- (C) Magnification
- (D) Resolution

Q74. PHY

In radiological physics, the SI unit of absorbed radiation dose, the Gray (Gy), is defined as:

- (A) 1 J kg
- (B) 1 J kg⁻¹
- (C) 1 J⁻¹ kg
- (D) 1 J⁻¹ kg⁻¹

Q75. PHY

A sample containing 32 g of a radioactive isotope decays such that only 2 g remains undecayed after 60 days. The half-life of this radioactive isotope is:

- (A) 2 days
- (B) 6 days
- (C) 10 days
- (D) 15 days

Q76. PHY

An elastic collision is defined physically as an isolated interaction in which:

- (A) Both total kinetic energy and total linear momentum are conserved
- (B) Total kinetic energy is conserved but total mechanical energy is not conserved
- (C) Total linear momentum is conserved but total kinetic energy is not conserved
- (D) Neither total kinetic energy nor total linear momentum is conserved

Q77. PHY

The time rate of change of linear velocity of a moving particle is defined as:

- (A) Force
- (B) Acceleration
- (C) Power
- (D) Energy

Q78. PHY

In ideal projectile motion launched from horizontal ground in the absence of aerodynamic resistance, the horizontal range is maximum when the projection angle θ is:

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

Q79. PHY

Regarding Newton's third law of motion and action-reaction force pairs, which of the following statements is NOT TRUE?

- (A) Action and reaction forces have the same fundamental physical nature
- (B) Action and reaction forces act along the same collinear line of action
- (C) Action and reaction forces never act on the same physical body
- (D) Action and reaction forces can cancel each other out to establish equilibrium

Q80. PHY

Two buses traveling along straight parallel lanes at speeds of 100 km h⁻¹ and 80 km h⁻¹ respectively pass each other while traveling in opposite directions. The magnitude of the velocity of one bus relative to the other bus is:

- (A) 100 km h⁻¹
- (B) 20 km h⁻¹
- (C) 80 km h⁻¹
- (D) 180 km h⁻¹

Q81. PHY

Which of the following pairs of projection angles will produce the exact same horizontal range for a projectile launched with identical speed over level ground?

- (A) 75° and 15°
- (B) 10° and 20°
- (C) 45° and 60°
- (D) 0° and 30°

Q82. PHY

The angle of projection of a projectile for which its maximum vertical height H and horizontal range R are numerically equal is approximately:

- (A) 45°
- (B) 90°
- (C) 0°
- (D) 76°

Q83. PHY

The explosion of an explosive projectile into multiple fragments in mid-air is an application of the fundamental:

- (A) Law of conservation of mechanical energy
- (B) Law of conservation of mass into energy
- (C) Law of conservation of linear momentum
- (D) Newton's first law of circular inertia

Q84. PHY

One imperial mechanical horsepower (hp) is equivalent in the SI system to:

- (A) 746 watts
- (B) 476 watts
- (C) 647 watts
- (D) 467 watts

Q85. PHY

The scalar dot product of a constant force vector $\mathbf{F}$ and the instantaneous velocity vector $\mathbf{v}$ represents:

- (A) Kinetic energy
- (B) Potential energy
- (C) Power
- (D) Work done

Q86. PHY

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

- (A) 36 MJ
- (B) 3.6 MJ
- (C) 36 kJ
- (D) 3.6 kJ

Q87. PHY

The amount of work done in moving a body from a given point in a gravitational field to a position of zero potential at infinity without imparting acceleration is called:

- (A) Absolute potential energy
- (B) Kinetic energy
- (C) Elastic potential energy
- (D) Electric potential

Q88. PHY

If the translational speed of a body of mass m is doubled, its resulting kinetic energy is expressed algebraically as:

- (A) mv^2
- (B) $2mv^2$
- (C) $\frac{1}{2}mv^2$
- (D) $4mv^2$

Q89. PHY

An industrial electric motor is rated at 2 hp. Assuming 100% operational efficiency, its output power rating in watts is:

- (A) 1500 W
- (B) 742 W
- (C) 148 W
- (D) 1492 W

Q90. PHY

One radian of angular displacement is equivalent in sexagesimal degrees to approximately:

- (A) 53.7°
- (B) 73.5°
- (C) 57.3°
- (D) 37.5°

Q91. PHY

The minimum orbital velocity required to place and maintain an artificial satellite in a stable circular low Earth orbit is called the:

- (A) Terminal velocity
- (B) Escape velocity
- (C) Critical velocity
- (D) Average velocity

Q92. PHY

A flywheel completes 12 revolutions in an elapsed time of 4 seconds. Its average angular velocity in radians per second is approximately:

- (A) 24.6 rad s^{-1}
- (B) 16.8 rad s^{-1}
- (C) 10.4 rad s^{-1}
- (D) 18.8 rad s^{-1}

Q93. PHY

When a particle executes uniform circular motion in a plane, the direction of its centripetal acceleration vector is always:

- (A) Directed radially inward toward the center of the circular path
- (B) Directed along the tangent to the curve in the direction of motion
- (C) Directed along the tangent to the curve opposite to the direction of motion
- (D) Directed radially outward away from the center of rotation

Q94. PHY

In a ripple tank experiment using a point light source above water waves, the crest of a surface wave acts optically like a:

- (A) Convex lens
- (B) Concave lens
- (C) Convex mirror
- (D) Plane mirror

Q95. PHY

The speed of sound in air is independent of which of the following physical variables at constant temperature?

- (A) Relative moisture content
- (B) Ambient hydrostatic pressure
- (C) Gas temperature
- (D) Gas density

ENG SECTION: ENGLISH

Questions 96 to 110 (15 MCQs)

Q96. ENG

Choose the grammatically and punctuationally correct sentence:

- (A) He had no worries his pension was adequate and there was a little money saved up besides.
- (B) He had no worries, his pension was adequate and there was a little money saved up besides.
- (C) He had no worries; his pension was adequate, and there was a little money saved up besides.
- (D) He had no worries: his pension was adequate and there was a little money saved up besides.

Q97. ENG

Identify the error and choose the correctly structured sentence:

- (A) There's Mr. Hashim whom they say is the best portrait painter in the town.
- (B) There's Mr. Hashim, who they say is the best portrait painter in the town.
- (C) There's Mr. Hashim which they say is the portrait painter in the town.
- (D) There's Mr. Hashim who they say is best portrait painter in the town.

Q98. ENG

Complete the sentence with correct subject-verb agreement:

'A full description of car accidents _____ reported.'

- (A) are
- (B) have been
- (C) was
- (D) were

Q99. ENG

Select the grammatically correct verb form to complete the sentence:

'Ahmad _____ me for a long time.'

- (A) has known
- (B) have known
- (C) knows
- (D) knew

Q100. ENG

In the sentence, 'He is appreciated for being ambidextrous', the underlined vocabulary word means:

- (A) Demonstrating exceptional quickness and physical agility
- (B) Displaying profound intellectual wisdom and strategic judgment
- (C) Able to use both the right and left hands with equal skill and facility
- (D) Remaining strictly focused and directly to the point

Q101. ENG

In the sentence, 'He visited the ghettos for the first time', the underlined vocabulary word means:

- (A) Affluent and elite suburban residential quarters
- (B) Improverished and underprivileged urban areas
- (C) Pristine and meticulously sanitary commercial districts
- (D) Modern, planned high-rise technological parks

Q102. ENG

Select the appropriate collective noun to complete the sentence:

'My friend has a fine _____ of old stamps.'

- (A) Group
- (B) Bridge
- (C) Band
- (D) Collection

Q103. ENG

Choose the grammatically correct sentence conforming to subject-verb agreement:

- (A) Every one of the prisons are full.
- (B) Every one of the prisons had full.
- (C) Every one of the prisons have full.
- (D) Every one of the prisons is full.

Q104. ENG

Select the grammatically correct verb form to complete the sentence:

'The headmaster _____ to speak to you.'

- (A) Wants
- (B) is wanting
- (C) was wanting
- (D) want

Q105. ENG

Complete the sentence with correct subject-verb agreement:

'Knowledge and wisdom _____ no time for connection.'

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

Q106. ENG

Complete the sentence with correct subject-verb agreement:

'Each of the boys _____ to ride.'

- (A) loves
- (B) love
- (C) are loving
- (D) have loved

Q107. ENG

Choose the sentence that is correctly punctuated and structured:

- (A) Mr. Shan with his family together goes to England.
- (B) Mr. Shan, together with his family, goes to England.
- (C) Mr. Shan, together with his family, go to England.
- (D) Mr. Shan, with his family, go to England together.

Q108. ENG

Identify the error and choose the correctly capitalized and structured sentence:

- (A) The english man thinks that he and his country are the best.
- (B) The English man think that he and his country are the best.
- (C) The English man thinks that he and his country are the best.
- (D) The English man think that he and his country are best.

Q109. ENG

Select the option containing the correct orthographic spelling:

- (A) Appratus
- (B) Aprattus
- (C) Appretis
- (D) Apparatus

Q110. ENG

Select the option containing the correct orthographic spelling:

- ☐ A Mercenary
 - ☐ B Mersanary
 - ☐ C Mercenary
 - ☐ D Mersenary
-

CHEM SECTION: CHEMISTRY

Questions 111 to 150 (40 MCQs)

Q111. CHEM

Which of the following metal halide compounds exhibits significant covalent character in its chemical bonding?

- (A) NaCl
- (B) MgCl_2
- (C) AlCl_3
- (D) KCl

Q112. CHEM

Which of the following periodic properties increases progressively down Group 1 (alkali metals) from lithium to cesium?

- (A) First ionization energy
- (B) Chemical reactivity
- (C) Electron affinity
- (D) Electronegativity

Q113. CHEM

The aqueous solubility of Group 2 (alkaline earth metal) sulfate salts behaves in which of the following manners down the group from BeSO_4 to BaSO_4 ?

- (A) Decreases progressively down the group
- (B) Increases progressively down the group
- (C) Remains constant throughout the group
- (D) First increases from beryllium to calcium and then decreases

Q114. CHEM

Geometric isomerism (cis-trans isomerism) is typically exhibited by which of the following homologous series of hydrocarbons?

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

Q115. CHEM

Benzene can be synthesized directly in the laboratory from phenol by heating it with which of the following reducing agents?

- (A) Reduction with hydrogen in the presence of nickel
- (B) Reduction with aqueous alkali
- (C) Reduction with zinc dust
- (D) Reduction with concentrated mineral acids

Q116. CHEM

The Lucas test utilizes a solution of anhydrous zinc chloride in concentrated hydrochloric acid to identify and distinguish between:

- (A) Alkyl halides
- (B) Alkenes
- (C) Alcohols
- (D) Carboxylic acids

Q117. CHEM

Under standard ambient conditions, pure phenol exhibits which of the following sets of physical characteristics?

- (A) Colorless amorphous solid
- (B) Colorless to white crystalline deliquescent solid
- (C) Colorless amorphous deliquescent solid
- (D) Viscous non-hygroscopic liquid

Q118. CHEM

The Cannizzaro reaction is a base-catalyzed redox disproportionation characteristic of which of the following carbonyl compounds?

- (A) Formaldehyde
- (B) Acetaldehyde
- (C) Acetone
- (D) Butanone

Q119. CHEM

Which of the following qualitative analytical tests is used to detect the presence of a ketone group and distinguish it from aldehydes?

- (A) Benedict's solution test
- (B) Fehling's solution test
- (C) Sodium nitroprusside test
- (D) Tollens' silver mirror test

Q120. CHEM

Low molecular weight aliphatic carboxylic acids are completely miscible with water primarily because they:

- (A) Exhibit high chemical reactivity
- (B) Have low melting points
- (C) Form extensive intermolecular hydrogen bonds with water
- (D) Possess high liquid densities

Q121. CHEM

Which of the following mathematical relationships represents the equation of state for an ideal gas?

- (A) $PV = nRT$
- (B) $PT = nRV$
- (C) $P = nRT$
- (D) $T = \frac{nPV}{R}$

Q122. CHEM

To prevent the volume of an ideal gas from expanding when its mass (moles) is increased, how should experimental conditions be adjusted?

- (A) Temperature is increased and pressure is lowered
- (B) Both temperature and pressure are decreased
- (C) Both temperature and pressure are increased
- (D) Temperature is lowered and pressure is increased

Q123. CHEM

Which thermodynamic variable from the ideal gas equation is held strictly constant when applying the classical gas laws (Boyle's, Charles's, and Gay-Lussac's laws)?

- (A) Volume
- (B) Temperature
- (C) Pressure
- (D) Number of moles

Q124. CHEM

Which of the following volatile organic and inorganic liquids displays the highest rate of evaporation at room temperature?

- (A) Acetone
- (B) Ethanol
- (C) Water
- (D) Ethylene glycol

Q125. CHEM

The specific heat capacity of pure liquid water under standard conditions is approximately:

- (A) $4.18 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$
- (B) $9.82 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$
- (C) $6.04 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$
- (D) $8.47 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1}$

Q126. CHEM

The normal boiling point of a covalent organic compound is elevated most substantially by the presence of:

- (A) Dipole-induced dipole interactions
- (B) London dispersion forces
- (C) Intramolecular hydrogen bonding
- (D) Intermolecular hydrogen bonding

Q127. CHEM

Which of the following fundamental chemical properties explains why ionic substances dissolve readily in liquid water?

- (A) Water has a molar mass of 18.02 g mol^{-1}
- (B) Water forms coordinate covalent dative bonds with cations
- (C) Water is a bent polar molecule with a high dielectric constant
- (D) Liquid water exhibits high physical density

Q128. CHEM

In crystalline solid-state chemistry, diamond is classified as a:

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

Q129. CHEM

Which of the following allotropic carbon nanomaterials is described as being 'as light as a feather and stronger than steel'?

- (A) Graphite
- (B) Graphene
- (C) Mercury
- (D) Diamond

Q130. CHEM

Under normal homeostatic physiological conditions, the pH of arterial human blood is maintained within the narrow range of:

- (A) 7.35 to 7.45
- (B) 8.35 to 8.45
- (C) 6.35 to 7.45
- (D) 5.57 to 6.57

Q131. CHEM

In the isotopic nuclide notation $^{23}_{11}\text{Na}$, the total number of protons present in the nucleus is:

- (A) 23
- (B) 12
- (C) 11
- (D) 34

Q132. CHEM

One mole of pure ethanol ($\text{C}_2\text{H}_5\text{OH}$) and one mole of pure ethane (C_2H_6) are identical in which of the following quantities?

- (A) Total mass in grams
- (B) Total number of constituent atoms
- (C) Total number of electrons
- (D) Total number of molecules

Q133. CHEM

The initial analytical step in determining the empirical formula of an unknown chemical compound from experimental combustion data is:

- (A) Calculating the simplest whole-number atomic ratio
- (B) Determining the percentage mass composition of each constituent element
- (C) Calculating the number of gram-atoms (moles) of each element
- (D) Multiplying fractional mole ratios by an integer

Q134. CHEM

The number of moles of carbon dioxide (CO_2) that contains exactly 16 g of combined oxygen is:

- (A) 0.25 mol
- (B) 0.50 mol
- (C) 1.00 mol
- (D) 1.50 mol

Q135. CHEM

The percentage composition by mass of carbon and oxygen in pure carbon dioxide (CO_2) is approximately:

- (A) 30.45% Carbon and 69.54% Oxygen
- (B) 24.22% Carbon and 75.78% Oxygen
- (C) 27.37% Carbon and 72.72% Oxygen
- (D) 41.68% Carbon and 58.12% Oxygen

Q136. CHEM

The maximum number of electrons that can occupy a p subshell is:

- (A) 2
- (B) 6
- (C) 10
- (D) 14

Q137. CHEM

Applying the $(n + l)$ rule of electronic configuration, which of the following permissible atomic orbitals possesses the highest energy level?

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

Q138. CHEM

Compared to the rest mass of a proton, the rest mass of an electron is approximately:

- (A) 1836 times greater than the mass of a proton
- (B) 1836 times less than the mass of a proton
- (C) Equal to the mass of a proton
- (D) 1836 times greater than the mass of a hydrogen atom

Q139. CHEM

The three-dimensional geometric shape of an atomic orbital cloud is determined by which quantum number?

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

Q140. CHEM

The rule stating that electrons occupy degenerate orbitals singly with parallel spins before any single orbital is doubly occupied is:

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

Q141. CHEM

Which term describes a stable chemical solution in which dissolved solute is in dynamic physical equilibrium with excess undissolved solute at a given temperature?

- (A) Dilute solution
- (B) Saturated solution
- (C) Unsaturated solution
- (D) Supersaturated solution

Q142. CHEM

The rate of a chemical reaction generally depends on which of the following physical and chemical factors?

- (A) Reactant concentration
- (B) System temperature
- (C) Presence of a catalyst
- (D) All of these factors

Q143. CHEM

Which of the following statements regarding the rate of a chemical reaction is NOT TRUE?

- (A) The concentration of reactants has no effect on the rate of a reaction
- (B) Increasing the surface area of solid reactants increases the reaction rate
- (C) Raising the temperature generally accelerates the rate of a reaction
- (D) Adding a suitable catalyst alters the reaction rate

Q144. CHEM

The standard enthalpy change of combustion (ΔH_c°) is always an exothermic process because:

- (A) Energy absorbed during bond breaking is greater than energy released during bond formation
- (B) Energy released during product bond formation exceeds energy absorbed during reactant bond breaking
- (C) Combustion reactions occur without breaking chemical bonds
- (D) Oxygen gas contains unusually weak chemical bonds

Q145. CHEM

One thermochemical calorie (1 cal) is exactly equivalent in SI joules to:

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

Q146. CHEM

The standard electrode potential (E°) of the Standard Hydrogen Electrode (SHE) is assigned a reference value of:

- (A) 10.0 V
- (B) +1.0 V
- (C) -1.0 V
- (D) 0.00 V

Q147. CHEM

During the electrolysis of an aqueous or molten electrolyte in an electrolytic cell, reduction occurs at the:

- (A) Anode
- (B) Salt bridge
- (C) Cathode
- (D) Auxiliary reference terminal

Q148. CHEM

The state of hybridization of both carbon atoms in ethene ($\text{H}_2\text{C}=\text{CH}_2$) is:

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

Q149. CHEM

Which of the following covalent molecules possesses a permanent net dipole moment and is classified as polar?

- (A) CCl_4
- (B) AlCl_3
- (C) CO_2
- (D) HCl

Q150. CHEM

The first electron affinity generally decreases (becomes less exothermic) descending down a main group of the periodic table because the:

- (A) Nuclear proton number increases
- (B) Effective nuclear shielding decreases
- (C) Atomic radius increases progressively
- (D) Effective nuclear charge increases substantially

OFFICIAL VERIFIED ANSWER KEY

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

SUBJECT-WISE PERFORMANCE BREAKDOWN

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

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Estimated NUMS Merit Aggregate: ----- %

PROPOLIS COGNITIVE ERROR AUTOPSIES

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

Question #1 Key: (B)

BIOLOGY
01. Cell

Which organelle would be more abundant in a secretory cell than in a non-secretory cell?

CORE CONCEPT & DERIVATION

The Golgi complex functions as the primary packaging, processing, and sorting center for proteins synthesized on the rough endoplasmic reticulum that are destined for exocytosis.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Secretory cells (such as pancreatic acinar cells or plasma B cells) continuously produce, modify, concentrate, and package proteins into secretory vesicles.
- The Golgi apparatus receives transport vesicles from the rough endoplasmic reticulum at its cis face, modifies oligosaccharide chains, packages products, and buds secretory vesicles from its trans face.
- Consequently, cells specialized for high secretory activity exhibit a prominently enlarged and highly developed Golgi complex relative to quiescent or non-secretory cells.

Why other options are incorrect:

- **Option A:** Lysosomes contain acid hydrolases responsible for intracellular degradation, phagocytosis, and autolysis, rather than the packaging and export of secretory proteins.
- **Option C:** Centrioles organize the mitotic spindle apparatus during nuclear division and are abundant during centrosome replication in dividing cells, not specifically in secretory cells.
- **Option D:** Large central vacuoles are characteristic of plant cells for maintaining turgor pressure; animal secretory cells utilize tiny secretory vesicles rather than expansive vacuoles.

Question #2 Key: (C)

BIOLOGY
01. Cell

The structure which disappears during cell division is the:

CORE CONCEPT & DERIVATION

During the prophase and prometaphase of open mitosis in eukaryotic cells, phosphorylation of nuclear lamins induces disassembly of the nuclear envelope and dissolution of the nucleolus, causing the morphological nucleus to disappear.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- As a cell transitions from interphase to mitosis (specifically late prophase into prometaphase), cyclin-dependent kinase 1 (CDK1) phosphorylates the nuclear lamina.
- This biochemical cascade causes the nuclear envelope to fragment into small vesicles, transcription ceases, and the nucleolus disintegrates.
- Because the boundary and structural integrity of the nucleus are disassembled to permit mitotic spindle access to kinetochores, the nucleus disappears as an intact entity until reassembly in telophase.

Why other options are incorrect:

- **Option A:** Vacuoles remain distributed within the cytoplasm throughout cell division and are partitioned between the two daughter cells.
- **Option B:** Lysosomes persist intact in the cytoplasm and undergo passive or organized distribution into daughter cells during cytokinesis.
- **Option D:** The endoplasmic reticulum fragments into smaller cisternae and tubular networks distributed throughout the cytoplasm, but it does not completely dissolve or disappear like the organized nucleus.

Question #3 Key: (A)

BIOLOGY
01. Cell

The enzyme ATP synthase is located on the membrane of which organelle?

CORE CONCEPT & DERIVATION

ATP synthase is a multi-subunit transmembrane protein complex embedded in the inner mitochondrial membrane (as well as the thylakoid membrane of chloroplasts) that catalyzes ATP formation utilizing a proton electrochemical gradient.

Formula / Rule / Reaction:



Solution:

- During cellular respiration, electron transport complexes (I, III, and IV) pump protons from the mitochondrial matrix into the intermembrane space, creating a proton motive force.
- Protons flow down their electrochemical gradient back into the matrix exclusively through the F_0 subunit of ATP synthase embedded in the inner mitochondrial membrane (cristae).
- This flow drives the rotary catalytic mechanism of the F_1 subunit facing the matrix, synthesizing ATP from ADP and inorganic phosphate.

Why other options are incorrect:

- **Option B:** The nuclear envelope possesses nuclear pore complexes for macromolecular transport, not ATP synthase complexes.
- **Option C:** The lysosomal membrane contains vacuolar-type H^+ -ATPase (V-ATPase) that consumes ATP to pump protons inward, rather than ATP synthase which generates ATP.
- **Option D:** Vacuolar membranes (tonoplasts) maintain turgor and store metabolites using ATP-dependent pumps, but they do not synthesize ATP via chemiosmosis.

Question #4 Key: (D)

BIOLOGY
01. Cell

Spherical sacs surrounded by a single membrane and containing hydrolytic enzymes are called:

CORE CONCEPT & DERIVATION

Lysosomes are single-membrane bound vesicular organelles containing approximately 40 to 50 distinct acid hydrolases active at an acidic internal pH of 4.5 to 5.0.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Lysosomes bud from the trans-Golgi network as primary lysosomes, encapsulated by a single phospholipid bilayer.
- Inside the lumen, they harbor hydrolytic enzymes including proteases, lipases, nucleases, and glycosidases synthesized in the rough endoplasmic reticulum.
- These enzymes function optimally in acidic environments to degrade phagocytosed foreign materials, cellular debris, and damaged organelles (autophagy).

Why other options are incorrect:

- **Option A:** Mitochondria are double-membrane bound organelles with outer and inner membranes specialized for oxidative phosphorylation, not single-membrane hydrolytic sacs.
- **Option B:** Golgi bodies consist of a series of flattened, disc-shaped membranous sacs called cisternae involved in chemical modification and sorting, not specialized digestive sacs.
- **Option C:** Chloroplasts are double-membrane bound organelles containing thylakoids and stroma responsible for photosynthesis.

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

Except during nuclear division, the nucleus contains chromosomes in a loosely coiled, dispersed...

CORE CONCEPT & DERIVATION

During interphase, eukaryotic genomic DNA is complexed with basic histone proteins into a relaxed, extended nucleoprotein network termed chromatin to permit transcription and replication.

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

- In a non-dividing cell, chromosomes are not individually visible under a light microscope because they exist as uncoiled, slender threads called chromatin.
- This decondensed structure ensures that RNA polymerases and transcription factors have physical access to promoter regions of genes.
- Chromatin condenses into tightly coiled, distinct chromosomes only during prophase of nuclear division (mitosis or meiosis).

Why other options are incorrect:

- **Option A:** Genes are specific functional segments or sequences of DNA nucleotides that encode functional polypeptides or RNA molecules, not the overall structural state of the chromosome.
- **Option B:** Ribosomes are ribonucleoprotein complexes situated in the cytoplasm or on the rough endoplasmic reticulum responsible for translating mRNA into protein.
- **Option D:** Histones are specific basic structural proteins that form the core octamer around which DNA winds; they do not encompass the entire dispersed nucleoprotein material itself.

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

Within the nucleus, ribosomal subunits are assembled by the:

CORE CONCEPT & DERIVATION

The nucleolus is a dense, non-membrane bound subnuclear structure organized around nucleolar organizer regions (NORs) dedicated to transcribing ribosomal RNA (rRNA) and assembling ribosomal subunits.

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

- The nucleolus contains genes for 18S, 5.8S, and 28S rRNAs, which are transcribed by RNA polymerase I into a pre-rRNA precursor.
- Ribosomal proteins synthesized in the cytoplasm enter the nucleus via nuclear pores and assemble with processed rRNA within the nucleolus.
- The assembled small (40S) and large (60S) subunits are separately exported to the cytoplasm, where they combine on mRNA during translation.

Why other options are incorrect:

- **Option B:** The nuclear envelope is a double membrane that delineates the nucleoplasm from the cytoplasm and regulates nucleocytoplasmic transport via nuclear pores.
- **Option C:** The rough endoplasmic reticulum serves as a platform for translating secretory and membrane proteins; it does not synthesize or assemble ribosomal subunits inside the nucleus.
- **Option D:** The kinetochore is a proteinaceous structure assembled on the centromere of chromosomes that serves as the attachment site for spindle microtubules during mitosis.

Question #7 Key: (C)BIOLOGY
01. Cell

Which of the following descriptions is correct for the plant cell wall?

CORE CONCEPT & DERIVATION

The plant cell wall is a non-living, porous extracellular matrix composed predominantly of cellulose microfibrils, hemicellulose, and pectin, which offers structural support while offering no barrier to water and dissolved solutes.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Unlike the selective plasma membrane, the primary cell wall has large spaces between its interwoven cellulose microfibrils.
- These microfibrillar pores readily allow the unhindered passage of water, mineral ions, and small solutes up to several thousand Daltons.
- Therefore, the cell wall is classified biologically as fully (freely) permeable, with selective permeability residing entirely within the underlying cell membrane.

Why other options are incorrect:

- **Option A:** Semi-permeable membranes permit the movement of solvent molecules (water) while blocking all solute molecules; the cell wall allows both solutes and solvent to pass.
- **Option B:** Differentially (selectively) permeable describes the living plasma membrane, which regulates the entry and exit of specific ions and polar molecules.
- **Option D:** Completely impermeable would prevent water and mineral uptake, which would cause cell death; the normal cell wall readily conducts extracellular fluids via the apoplast pathway.

Question #8 Key: (D)BIOLOGY
01. Cell

Why is the plasma membrane described as asymmetrical?

CORE CONCEPT & DERIVATION

Membrane asymmetry refers to the non-uniform, polarized distribution of phospholipids, carbohydrates, and proteins across the inner (cytoplasmic) and outer (exoplasmic) leaflets of the lipid bilayer.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The outer leaflet of the plasma membrane is rich in phosphatidylcholine, sphingomyelin, and glycolipids, whereas the inner leaflet is enriched in phosphatidylserine and phosphatidylethanolamine.
- Furthermore, carbohydrate chains of glycoproteins and glycolipids (the glycocalyx) project exclusively toward the extracellular space for recognition and protection.
- Peripheral and transmembrane proteins also possess strict directional orientation, rendering the two faces structurally and biochemically distinct.

Why other options are incorrect:

- **Option A:** According to the fluid mosaic model, membrane proteins exhibit lateral mobility and rotation rather than remaining completely static.
- **Option B:** The arrangement of hydrophilic heads facing outward and hydrophobic tails sequestered inward occurs on both leaflets and is an example of amphipathic thermodynamic stabilization, not asymmetry.
- **Option C:** Cholesterol inserts intercalated within both the outer and inner leaflets to modulate membrane fluidity, rather than being confined solely to the inside.

Question #9 Key: (A)BIOLOGY
01. Cell

The cell membrane contains which structures through which the transport of materials takes place...

CORE CONCEPT & DERIVATION

Transmembrane channel and carrier proteins form charged internal hydrophilic pathways (charged pores) across the hydrophobic lipid bilayer, enabling ions and polar substances to cross by passive or active transport.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The hydrophobic core of the phospholipid bilayer is impermeable to inorganic ions (such as Na^+ , K^+ , Ca^{2+}) and polar macromolecules.
- Integral membrane transport proteins span the bilayer, folding into cylindrical pores lined with hydrophilic and charged amino acid residues.
- These charged pores facilitate selective passive diffusion (ion channels) or couple solute movement to energy sources like ATP hydrolysis (primary active transport pumps).

Why other options are incorrect:

- Option B:** Fatty acid tails form a hydrophobic barrier that repels charged and hydrophilic solutes, preventing their unassisted passage.
- Option C:** Cholesterol stabilizes lipid packing and moderates fluidity; it does not form transport channels for solutes.
- Option D:** The glycocalyx consists of peripheral carbohydrate chains involved in cell recognition and adherence, not trans-bilayer solute transport.

Question #10 Key: (B)BIOLOGY
01. Cell

Which biochemical component of the plasma membrane primarily regulates membrane fluidity?

CORE CONCEPT & DERIVATION

Membrane fluidity is determined by the lipid composition of the bilayer, specifically the ratio of unsaturated to saturated fatty acid tails and the presence of cholesterol.

Formula / Rule / Reaction:

$$\text{Fluidity} \propto \frac{\text{Unsaturated Fatty Acid Content} \times \text{Temperature}}{\text{Saturated Fatty Acid Content}}$$

Solution:

- The lipid bilayer forms the fluid matrix of the cell membrane. Cis-double bonds in unsaturated hydrocarbon tails create kinks that prevent close packing, enhancing fluidity at lower temperatures.
- Cholesterol (a sterol lipid) acts as a bidirectional fluidity buffer: it restrains phospholipid movement at high temperatures to prevent excessive fluidity and prevents tight clustering at low temperatures to prevent solidification.
- Thus, the lipid component directly controls the physical fluidity and mechanical flexibility of the membrane.

Why other options are incorrect:

- Option A:** Glycoproteins act in cell-to-cell adhesion, immunological signaling, and ligand reception, not the bulk physical viscosity of the bilayer.
- Option C:** Carrier proteins mediate selective solute transport across the membrane and do not determine membrane lipid dynamics.
- Option D:** Membrane carbohydrates occur solely as short branched oligosaccharide chains on the exterior surface for identification and protection.

Question #11 Key: (B)BIOLOGY
01. Cell

A group of ribosomes attached to a single mRNA molecule is known as a polysome. This ribosomal ...

CORE CONCEPT & DERIVATION

The association and structural cohesion of the small and large ribosomal subunits, as well as their stability along the mRNA transcript, require a precise physiological concentration of divalent magnesium ions.

Formula / Rule / Reaction:

$\text{Small Subunit (40S/30S)} + \text{Large Subunit (60S/50S)} \rightleftharpoons \text{Active Ribosome (80S/70S)}$

- Ribosomal RNA molecules possess negatively charged phosphate backbones that naturally repel each other due to electrostatic forces.
- Divalent magnesium ions (Mg^{2+}) shield these negative charges, allowing the ribosomal subunits to associate into functional 70S or 80S units and assemble as polysomes on mRNA.
- If the Mg^{2+} concentration drops below approximately 10^{-3} M, the subunits dissociate into inactive fragments, halting protein synthesis.

Why other options are incorrect:

- Option A:** Monovalent sodium ions (Na^+) regulate osmotic balance and nerve action potentials; they do not structurally stabilize ribosomal subunit assembly.
- Option C:** Calcium ions (Ca^{2+}) function primarily as intracellular secondary messengers and trigger muscle contraction, not ribosome stabilization.
- Option D:** Monovalent potassium ions (K^+) are essential for cellular resting potentials and enzyme activation, but they cannot fulfill the divalent charge-neutralizing role of Mg^{2+} .

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

An automatic, involuntary, and rapid response to any external or internal stimulus is called a:

CORE CONCEPT & DERIVATION

A reflex is an involuntary, rapid, stereotyped, and unlearned motor response to a sensory stimulus, mediated directly through a reflex arc without conscious cerebral intervention.

Formula / Rule / Reaction:

Stimulus → Receptor → Sensory Neuron → Interneuron/CNS → Motor Neuron → Effector

Solution:

- When a receptor detects a change in the environment, nerve impulses travel along a reflex arc through the spinal cord or brainstem.
- The motor signal stimulates an effector (muscle or gland) immediately, bypassing the conscious analysis of the cerebral cortex.
- This rapid response protects the organism from severe bodily injury (for example, the withdrawal reflex upon touching a sharp or hot object).

Why other options are incorrect:

- Option B:** An instinct is a complex, innate, stereotyped behavior pattern involving an entire sequence of coordinated actions (such as bird migration or web weaving), rather than a single simple involuntary response.
- Option C:** Taxis is the directional movement of a whole motile organism toward or away from an external directional stimulus (such as chemotaxis in bacteria).
- Option D:** Tropism is a slow, directional growth response of a sessile organism (typically a plant) toward or away from a stimulus (such as phototropism).

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

The resting membrane potential of a typical human neuron measures approximately:

CORE CONCEPT & DERIVATION

The resting membrane potential is the steady-state electrical potential difference across the plasma membrane of an excitable cell at rest, primarily established by potassium leak channels and the electrogenic Na^+/K^+ -ATPase.

Formula / Rule / Reaction:

$$V_m = \frac{RT}{F} \ln \left(\frac{P_K[\text{K}^+]_o + P_{\text{Na}}[\text{Na}^+]_o + P_{\text{Cl}}[\text{Cl}^-]_i}{P_K[\text{K}^+]_i + P_{\text{Na}}[\text{Na}^+]_i + P_{\text{Cl}}[\text{Cl}^-]_o} \right) \approx -70 \text{ mV}$$

Solution:

- The intracellular compartment contains a high concentration of K^+ ions and non-diffusible negatively charged proteins, while the extracellular fluid contains high Na^+ and Cl^- .
- Resting neuronal membranes are substantially more permeable to K^+ than to Na^+ , allowing K^+ to diffuse out down its concentration gradient through open leak channels.
- This net outward movement of positive charge renders the inner surface of the membrane electrically negative relative to the outside, generating a standard resting potential of -70 mV .

Why other options are incorrect:

- Option B:** The unit of volts (V) is three orders of magnitude too large; biological membrane potentials operate in millivolts (mV).
- Option C:** A value of $+70 \text{ mV}$ represents a positive intracellular state near the equilibrium potential for Na^+ , not a resting cell state.
- Option D:** A potential of -90 mV is characteristic of ventricular cardiac myocytes or skeletal muscle fibers, whereas standard neurons rest at -70 mV .

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

Sensory receptors specialized for detecting light, discriminative touch in hairless skin are:

CORE CONCEPT & DERIVATION

Meissner corpuscles (tactile corpuscles) are rapidly adapting, encapsulated mechanoreceptors located in the dermal papillae of glabrous (hairless) skin, specialized for light touch and low-frequency vibration.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Meissner corpuscles consist of an unmyelinated nerve ending surrounded by fluid-filled lamellar Schwann cells, situated directly beneath the epidermal-dermal junction.
- Because of their superficial location in fingertips, palms, and soles, they have small receptive fields with high spatial resolution.
- They respond vigorously to light touch, dynamic skin deformation, and textured surfaces.

Why other options are incorrect:

- Option A:** Pacinian corpuscles are deeply situated, rapidly adapting mechanoreceptors with concentric onion-like lamellae specialized for detecting deep pressure and high-frequency vibrations.
- Option B:** Olfactory receptors are specialized chemoreceptors located in the nasal epithelium for detecting airborne chemical odorants.
- Option D:** Nociceptors are naked free nerve endings distributed across tissues specialized for transducing tissue-damaging mechanical, thermal, or chemical stimuli as pain.

Question #15 Key: (D)BIOLOGY
06. Digestion/Nutrition

Which of the following processes is NOT a physiological function of the human large intestine?

CORE CONCEPT & DERIVATION

The digestion and absorption of dietary proteins into free amino acids occurs almost entirely within the stomach and small intestine (duodenum and jejunum); the large intestine lacks the specialized transport systems for nutrient amino acid absorption.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The mucosa of the small intestine possesses extensive brush border microvilli with specialized sodium-dependent amino acid transporters that actively absorb digested amino acids into mesenteric capillaries.
- By the time chyme passes through the ileocecal valve into the cecum and colon, virtually all absorbable nutrients have been extracted.
- The primary functions of the large intestine are limited to absorbing water, consolidating feces, absorbing electrolytes (such as Na^+ and Cl^-), and housing symbiotic bacterial flora that synthesize vitamin K and biotin.

Why other options are incorrect:

- Option A:** The colon actively absorbs sodium and chloride ions across its epithelial cells, contributing to electrolyte conservation.
- Option B:** The large intestine absorbs approximately 90% of the remaining fluid presented to it (around 1.5 liters per day), compacting indigestible residue into solid feces.
- Option C:** Symbiotic gut microflora in the colon synthesize essential vitamins, particularly vitamin K and B-complex vitamins, which are absorbed locally.

Question #16 Key: (B)BIOLOGY
09. Respiration / Gaseous Exchange

Which anatomical passageway is shared by both the digestive and respiratory systems in human be...

CORE CONCEPT & DERIVATION

The pharynx is a funnel-shaped, fibromuscular passage located posterior to the oral and nasal cavities that serves as a common conduit for both ingested food and inhaled air.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The pharynx is divided into three regions: the nasopharynx (respiratory only), the oropharynx, and the laryngopharynx.
- Both the oropharynx and laryngopharynx transmit food boluses from the oral cavity into the esophagus and air from the nasal cavity into the larynx.
- During swallowing (deglutition), the epiglottis cartilaginous flap folds downward over the laryngeal inlet, ensuring that food passes safely into the esophagus rather than the airway.

Why other options are incorrect:

- Option A:** The trachea (windpipe) is an exclusively respiratory conduit that conducts air from the larynx into the primary bronchi.
- Option C:** The larynx (voice box) is strictly an airway structure situated between the pharynx and trachea that also houses the vocal folds.
- Option D:** The oesophagus is an exclusively digestive muscular tube that transports food and liquids from the pharynx down to the stomach via peristalsis.

Question #17 Key: (C)BIOLOGY
07. Circulation / Transport

In a healthy human heart, the rhythmic electrical impulses are initiated and regulated by the:

CORE CONCEPT & DERIVATION

The sinoatrial (SA) node acts as the primary physiological pacemaker of the mammalian heart due to having the fastest rate of spontaneous, rhythmic diastolic depolarization.

Formula / Rule / Reaction:

SA Node (70 to 80 bpm) → Atria → AV Node (40 to 60 bpm) → Bundle of His → Purkinje System (20 to 40 bpm)

Solution:

- Located in the posterior wall of the right atrium near the opening of the superior vena cava, the specialized pacemaker myocytes of the SA node exhibit unstable resting membrane potentials.
- Inward hyperpolarization-activated funny currents (I_f) and T-type calcium channels produce automatic prepotential drifting toward threshold.
- Because the SA node possesses the highest intrinsic firing frequency (70 to 80 action potentials per minute), it overrides secondary pacemakers via overdrive suppression, setting the rhythm of normal cardiac contraction.

Why other options are incorrect:

- **Option A:** Purkinje fibers are specialized conduction myofibers that rapidly propagate electrical impulses throughout ventricular myocardium; their intrinsic firing rate (20 to 40 bpm) only manifests during complete heart block.
- **Option B:** The atrioventricular bundle transmits electrical impulses from the AV node across the fibrous skeleton of the heart into the ventricles.
- **Option D:** The bundle of His is an alternative designation for the atrioventricular bundle; it does not set normal resting cardiac rhythm.

Question #18 Key: (D)BIOLOGY
08. Immunity

Which method helps develop active, long-lasting immunity against pathogenic bacteria?

CORE CONCEPT & DERIVATION

Vaccination introduces attenuated, inactivated, or subunit bacterial antigens into the body to stimulate a primary immune response and generate long-lived antigen-specific memory B and T cells without causing full-blown disease.

Formula / Rule / Reaction:

Antigen Exposure (Vaccine) → Clonal Selection → Effector Cells + Memory B/T Lymphocytes

Solution:

- When a vaccine is administered, antigen-presenting cells process the bacterial antigens and present them to helper T lymphocytes via MHC class II molecules.
- This activates naïve B lymphocytes to proliferate and differentiate into plasma cells that secrete high-affinity protective antibodies, while simultaneously creating memory B and T cell clones.
- Upon subsequent exposure to the living pathogenic bacterium, memory cells mount an accelerated, robust secondary immune response that neutralizes the pathogen before symptoms emerge.

Why other options are incorrect:

- **Option A:** Radiotherapy uses high-energy ionizing radiation to destroy malignant tumor cells by inducing lethal double-stranded DNA breaks; it severely suppresses the immune system.
- **Option B:** Chemotherapy involves cytotoxic chemical agents designed to eradicate rapidly dividing cancer cells or microbes, typically causing temporary immunosuppression.
- **Option C:** Antibiotic therapy directly kills (bactericidal) or inhibits the growth of (bacteriostatic) bacteria within an active infection; it does not confer long-lasting immunological memory.

Question #19 Key: (B)BIOLOGY
14. Reproduction

The normal gestation period in human beings is approximately:

CORE CONCEPT & DERIVATION

Human pregnancy typically spans approximately 280 days (40 weeks) calculated from the first day of the last normal menstrual period (LNMP), or approximately 266 days (38 weeks) from fertilization.

Formula / Rule / Reaction:

Gestation $\approx$ 280 days from LNMP $\approx$ 38 to 40 weeks $\approx$ 9 calendar months

Solution:

- In human obstetrics, clinical gestational age is measured from the onset of the woman's last menstrual cycle, yielding an expected duration of 40 weeks, or 280 days.
- From the actual biological moment of ovulation and subsequent fertilization, embryonic and fetal development encompasses 266 days (38 weeks).
- The standard clinical reference range for full-term human gestation spans 270 to 280 days (37 to 42 weeks).

Why other options are incorrect:

- **Option A:** 240 to 250 days (approximately 34 to 35 weeks) falls in the premature (preterm) delivery range, which is associated with neonatal respiratory distress due to immature surfactant production.
- **Option C:** 300 to 320 days represents a severely post-term, post-mature pregnancy that carries increased risk of placental insufficiency and fetal complications.
- **Option D:** 322 to 350 days is well past human physiological gestation limits.

Question #20 Key: (A)BIOLOGY
14. Reproduction

During the human menstrual cycle, after ovulation releases the secondary oocyte, the remaining ...

CORE CONCEPT & DERIVATION

Following ovulation under the influence of the LH surge, the collapsed wall of the ruptured Graafian follicle luteinizes into the corpus luteum, which secretes high amounts of progesterone to prepare the endometrium for implantation.

Formula / Rule / Reaction:

Ruptured Follicle $\xrightarrow{\text{LH Surge}}$ Corpus Luteum $\rightarrow$ Progesterone(primary) + Estrogen

Solution:

- The luteal phase of the ovarian cycle begins immediately following the extrusion of the secondary oocyte during ovulation.
- Granulosa and theca cells hypertrophy under the stimulus of luteinizing hormone (LH) into lutein cells, forming the vascularized corpus luteum.
- The corpus luteum primarily secretes progesterone (and moderate amounts of estradiol) to transform the proliferated uterine endometrium into a glandular, secretory tissue suited for blastocyst implantation.

Why other options are incorrect:

- **Option B:** Follicle-stimulating hormone (FSH) is synthesized and secreted by gonadotroph cells of the anterior pituitary gland, not the ovarian follicle.
- **Option C:** Luteinizing hormone (LH) is also an anterior pituitary glycoprotein hormone whose mid-cycle surge triggers ovulation and corpus luteum differentiation.
- **Option D:** Testosterone is the primary male androgen produced by Leydig cells of the testes; small amounts synthesized by ovarian stroma serve as biosynthetic precursors to estrogens.

Question #21 **Key: (D)**BIOLOGY
14. Reproduction

In the male reproductive system, the hormone that exerts negative feedback to regulate the rate...

CORE CONCEPT & DERIVATION

Inhibin is a peptide hormone secreted by the Sertoli cells of the testes that selectively suppresses the secretion of follicle-stimulating hormone (FSH) from the anterior pituitary via a negative feedback loop to moderate sperm production.

Formula / Rule / Reaction:

High Sperm Count → Sertoli Cells release Inhibin $\xrightarrow{(-)}$ Anterior Pituitary FSH Secretion → Spermatogenesis Normalizes

Solution:

- Spermatogenesis in the seminiferous tubules is stimulated by FSH, which binds to receptors on Sertoli (nurse) cells to promote sperm maturation.
- When the rate of spermatogenesis reaches high levels, Sertoli cells release the glycoprotein hormone inhibin into the bloodstream.
- Inhibin travels to the anterior pituitary gland, where it selectively inhibits the synthesis and exocytosis of FSH, modulating the ongoing rate of spermatogenesis.

Why other options are incorrect:

- **Option A:** Luteinizing hormone (LH) stimulates testicular interstitial Leydig cells to produce testosterone; it does not directly regulate the rate of spermatogenesis via feedback.
- **Option B:** Follicle-stimulating hormone stimulates rather than regulates by negative feedback the initiation and maintenance of spermatogenesis.
- **Option C:** Testosterone regulates LH and GnRH secretion through negative feedback at the hypothalamus and pituitary; while vital for spermatogenesis, inhibin is the specific factor tailored directly to regulating sperm production rate by monitoring Sertoli activity.

Question #22 **Key: (C)**BIOLOGY
14. Reproduction

The cervix is an anatomical division of the:

CORE CONCEPT & DERIVATION

The uterus consists of three major anatomical subdivisions: the superior dome-shaped fundus, the central body (corpus), and the inferior narrow neck termed the cervix.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The cervix uteri constitutes the lowermost cylindrical segment of the uterus that connects the uterine cavity to the lumen of the vagina.
- It contains the cervical canal, bounded by the internal os (opening into the uterine cavity) and the external os (opening into the vagina).
- It is composed of dense fibrous connective tissue that maintains structural containment of the developing fetus during pregnancy and dilates during parturition.

Why other options are incorrect:

- **Option A:** The vagina is an elastic, fibromuscular copulatory canal extending from the vulva up to the uterine cervix; the cervix projects into the vagina, but is anatomically a region of the uterus.
- **Option B:** The oviducts (Fallopian tubes) are paired bilateral tubes that extend from the uterine horns toward the ovaries, consisting of infundibulum, ampulla, and isthmus.
- **Option D:** The ovary is the female primary reproductive gonad responsible for gametogenesis (oogenesis) and steroid hormone production.

Question #23 **Key: (B)**BIOLOGY
11. Support & Movement

Which type of cartilage is the most abundant in the human body?

CORE CONCEPT & DERIVATION

Hyaline cartilage is the most prevalent form of specialized skeletal connective tissue in the human body, characterized by a glassy, homogeneous extracellular matrix rich in type II collagen and chondroitin sulfate proteoglycans.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Hyaline cartilage provides smooth, low-friction surfaces for gliding joints and imparts flexible structural support across multiple organ systems.
- It forms the entire embryonic skeletal model before endochondral ossification, and persists postnatally as articular cartilage covering joint surfaces of long bones.
- Additionally, hyaline cartilage constitutes the costal cartilages of the ribs, the epiphyseal growth plates, and the structural rings of the nose, larynx, trachea, and bronchi.

Why other options are incorrect:

- **Option A:** Fibrocartilage contains dense parallel bundles of type I collagen along with type II; it is limited to areas subjected to high tensile stress, such as intervertebral discs and the pubic symphysis.
- **Option C:** Elastic cartilage contains dense networks of branching elastin fibers; it is restricted to pliable structures including the external ear pinna, epiglottis, and Eustachian tubes.
- **Option D:** Calcified cartilage is a transient, hardened matrix formed during the progression of endochondral bone formation and is not an abundant permanent tissue type.

Question #24 **Key: (A)**BIOLOGY
11. Support & Movement

Which of the following is an example of an immovable fibrous joint known as a suture?

CORE CONCEPT & DERIVATION

Sutures (synarthroses) are rigid, immovable fibrous joints formed by thin layers of dense fibrous Sharpey's fibers that interlock the adjacent flat bones of the human cranium.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The skull bones (such as frontal, parietal, occipital, and temporal bones) articulate with each other along irregular, interdigitating edges held tightly by dense collagenous tissue.
- These specialized immovable fibrous joints are termed sutures (for example, the coronal, sagittal, and lambdoid sutures).
- They provide rigid mechanical protection for underlying neural structures of the brain while resisting displacement during trauma.

Why other options are incorrect:

- **Option B:** Intervertebral discs form cartilaginous joints (amphiarthroses or symphyses) that permit limited spinal flexibility and act as shock absorbers.
- **Option C:** Costal cartilages connect the ribs to the sternum as synchondroses (hyaline cartilaginous joints) to permit thoracic expansion during ventilation.
- **Option D:** The pubic symphysis is an amphiarthrodial cartilaginous joint joined by a fibrocartilaginous interpubic disc, not an immovable fibrous suture.

Question #25 Key: (B)BIOLOGY
11. Support & Movement

Which event does NOT occur during skeletal muscle contraction?

CORE CONCEPT & DERIVATION

According to the sliding filament theory of muscle contraction, thick (myosin) and thin (actin) filaments do not alter their physical lengths during sarcomere shortening; hence, the A-band remains strictly constant in length.

Formula / Rule / Reaction:

$$\text{Sarcomere Shortening} \implies \Delta L_{A\text{-band}} = 0, \quad \Delta L_{I\text{-band}} < 0, \quad \Delta L_{H\text{-zone}} < 0$$

Solution:

- The anisotropic band (A-band) represents the total longitudinal length of the thick myosin filaments within a sarcomere.
- During contraction, myosin cross-bridges pull actin filaments toward the center of the sarcomere (M-line), causing thin filaments to slide past thick filaments.
- As a result, the distance between adjacent Z-lines decreases, the isotropic band (I-band) shortens, and the central H-zone narrows or disappears entirely.
- Because thick filament length is unaltered, the A-band maintains a constant dimensions throughout contraction.

Why other options are incorrect:

- **Option A:** The I-band corresponds exclusively to thin actin filaments not overlapping thick filaments; as actin slides into the A-band, the I-band shortens.
- **Option C:** The H-zone represents the central region of the A-band containing only thick filaments; overlapping thin filaments occupy this space during maximal contraction, causing the H-zone to disappear.
- **Option D:** Z-lines define the boundaries of a sarcomere; cross-bridge cycling pulls them closer together as the entire muscle fiber contracts.

Question #26 Key: (A)BIOLOGY
11. Support & Movement

Smooth muscle cells are spindle-shaped, non-striated, and typically possess how many nuclei per...

CORE CONCEPT & DERIVATION

Smooth muscle tissue consists of individual fusiform (spindle-shaped) myocytes, each containing a single centrally placed, oval nucleus.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Smooth muscle cells lack the transverse myofibrillar striations characteristic of skeletal and cardiac muscle because myofilaments are arranged in a crisscross lattice rather than regular sarcomeres.
- Each cell is tapered at both ends and thickest in the middle, harboring exactly one nucleus situated at its widest central point.
- They are under involuntary autonomic neural and endocrine control, lining visceral walls such as the gut, blood vessels, and uterus.

Why other options are incorrect:

- **Option B:** Smooth muscle cells do not possess two nuclei; occasional binucleation is seen in cardiac myocytes, but smooth muscle is strictly uninucleated.
- **Option C:** Three nuclei is biologically incorrect for unfused embryonic or mature smooth myocytes.
- **Option D:** Multinucleated cells (syncytia) resulting from the fusion of numerous embryonic myoblasts are the defining anatomical characteristic of skeletal muscle fibers.

Question #27 Key: (B)BIOLOGY
15. Inheritance / Variation & Genetics

Which human ABO and Rh blood type is designated as the universal red blood cell donor?

CORE CONCEPT & DERIVATION

Type O-negative (O^-) red blood cells lack surface A, B, and Rh (D) antigens, enabling them to be transfused into recipients of any ABO/Rh blood group without eliciting acute hemolytic agglutination.

Formula / Rule / Reaction:Universal RBC Donor: O^- (Antigens: None; Antibodies in Plasma: Anti-A, Anti-B)**Solution:**

- Agglutination occurs when recipient plasma antibodies recognize and bind to foreign antigens on the donor erythrocyte surface.
- Because group O erythrocytes express neither antigen A nor antigen B, and the Rh-negative status denotes absence of the D antigen, the recipient's immune system encounters no target surface antigens.
- Consequently, packed red blood cells from an O^- donor can be safely administered in emergency situations when cross-matching is unavailable.

Why other options are incorrect:

- **Option A:** A^+ erythrocytes express both A and D surface antigens and will undergo immediate complement-mediated lysis if transfused into recipients with anti-A or anti-Rh antibodies (such as group B or O individuals).
- **Option C:** AB^+ red cells express A, B, and D antigens, making them compatible only with AB^+ recipients; however, AB^+ individuals act as universal plasma and RBC recipients.
- **Option D:** O^+ erythrocytes express the Rh D antigen, which triggers anti-Rh alloimmunization or hemolysis in Rh-negative recipients.

Question #28 Key: (C)BIOLOGY
05. Acellular Life

Which of the following characteristics of a virus represents a living characteristic?

CORE CONCEPT & DERIVATION

Viruses straddle the boundary between living organisms and non-living chemical complexes; genetic inheritance, reproduction inside a host, and spontaneous mutation are their primary biological (living) attributes.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- A defining hallmark of living systems is the possession of genetic material (DNA or RNA) that can undergo replication, recombination, and nucleotide sequence alterations (mutations).
- Viruses introduce mutations during viral genome replication, permitting evolutionary adaptation through natural selection and emergence of novel antigenic strains.
- In contrast, non-living materials possess fixed chemical formulas that cannot undergo Darwinian biological evolution.

Why other options are incorrect:

- **Option A:** The ability of viral particles (virions) to be precipitated into regular crystal lattices (as demonstrated by Wendell Stanley with tobacco mosaic virus) is a physical, non-living property shared with inorganic salts.
- **Option B:** The complete absence of cellular metabolic pathways, including respiratory phosphorylation, is a hallmark of non-living, inert macromolecular assemblies.
- **Option D:** Lacking ribosomes, tRNA, and ATP-generating machinery is an acellular (non-living) attribute requiring viruses to act as obligate intracellular parasites.

Question #29 Key: (A)BIOLOGY
16. Evolution

A group of natural populations whose individuals possess similar morphological and physiological...

CORE CONCEPT & DERIVATION

According to the biological species concept formulated by Ernst Mayr, a species consists of groups of interbreeding natural populations that are reproductively isolated from other such groups.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- A biological species represents the fundamental unit of taxonomic classification and evolutionary biology.
- Members of the same species share a common gene pool, possess closely identical anatomical, biochemical, and physiological adaptations, and can freely mate in nature to produce viable, fertile offspring.
- Reproductive isolating barriers (both pre-zygotic and post-zygotic) preserve species integrity by preventing permanent gene flow with other species.

Why other options are incorrect:

- **Option B:** A genus is a higher taxonomic category comprising an aggregation of one or more phylogenetically related species.
- **Option C:** A family is an even broader taxonomic hierarchy containing multiple related genera sharing major evolutionary adaptations.
- **Option D:** An order is an overarching taxonomic rank that groups multiple related families together (such as Carnivora or Primates).

Question #30 Key: (C)BIOLOGY
04. Bioenergetics

Under aerobic conditions, the complete oxidation of one molecule of glucose in prokaryotic cell...

CORE CONCEPT & DERIVATION

Prokaryotes generate a net theoretical yield of 38 ATP per glucose molecule because they lack mitochondria, avoiding the 2 ATP transport cost required in eukaryotes to shuttle cytosolic NADH across the mitochondrial membrane.

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

- In prokaryotic cells, glycolysis, the transition step, and the citric acid cycle all occur within the cytoplasm, while the respiratory electron transport chains reside on the plasma membrane.
- Consequently, the 2 molecules of NADH generated during glycolysis are already in direct physical contact with membrane electron transport complexes.
- Because no active transport across an organellar envelope is needed, the full theoretical yield of 38 ATP is preserved.

Why other options are incorrect:

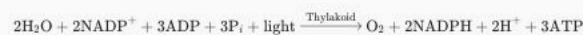
- **Option A:** 30 to 32 ATP represents modern stoichiometric empirical measurements in eukaryotic mitochondria accounting for proton leakage and transport gradients.
- **Option B:** 36 ATP represents the classic net theoretical yield in eukaryotic cells using the glycerol phosphate shuttle to import glycolytic NADH.
- **Option D:** 40 ATP represents the total gross ATP synthesized prior to deducting the 2 ATP invested during the preparatory phase of glycolysis.

Question #31 Key: (D)BIOLOGY
04. Bioenergetics

What are the primary chemical products generated by the light-dependent reactions of photosynth...

CORE CONCEPT & DERIVATION

The light-dependent reactions taking place in the thylakoid membranes of chloroplasts convert photon energy into chemical bond energy, producing ATP, NADPH (reduced NADP), and oxygen byproduct via photolysis.

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

- Photosystem II absorbs light energy, excites electrons, and catalyzes the photolytic splitting of water, which produces protons, free electrons, and molecular oxygen (O_2).
- Electrons flow down a photosynthetic electron transport chain, generating a proton gradient across the thylakoid membrane that drives ATP synthesis via photophosphorylation.
- Electrons re-energized at Photosystem I are transferred via ferredoxin-NADP+ reductase to reduce NADP^+ into NADPH.
- Both ATP and NADPH are released into the stroma to fuel the light-independent Calvin cycle.

Why other options are incorrect:

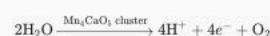
- **Option A:** RuBP (ribulose-1,5-bisphosphate) is a metabolic intermediate of the dark reactions (Calvin cycle) and reduced NAD (NADH) is a cofactor in respiration, not photosynthesis.
- **Option B:** GP (glycerate-3-phosphate) is synthesized during carbon fixation in the stroma, and photosynthesis utilizes NADP, not NAD.
- **Option C:** GP and RuBP are participants in the stroma-based Calvin cycle, not products of thylakoid light-dependent reactions.

Question #32 Key: (B)BIOLOGY
04. Bioenergetics

During the process of oxygenic photosynthesis, water molecules act as:

CORE CONCEPT & DERIVATION

In oxygenic photosynthesis, water molecules undergo light-driven enzymatic photolysis at the oxygen-evolving complex of Photosystem II, serving as the ultimate electron donor to replace excited electrons lost by P680 chlorophyll.

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

- Photo-oxidation of chlorophyll P680 creates a high-redox potential intermediate (P680^+) capable of extracting electrons from water.
- The oxygen-evolving complex splits water into electrons, protons, and molecular oxygen gas.
- The released electrons enter the electron transport chain to sustain continuous non-cyclic photophosphorylation, definitively establishing water as an electron donor.

Why other options are incorrect:

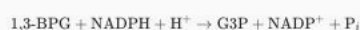
- **Option A:** Water releases protons (H^+) into the thylakoid lumen rather than accepting them; NADP^+ acts as the terminal proton/electron acceptor.
- **Option C:** Water does not directly reduce carbon dioxide; carbon dioxide is reduced enzymatically in the stroma by NADPH during the Calvin cycle.
- **Option D:** RuBP (ribulose-1,5-bisphosphate) acts as the biological acceptor for carbon dioxide, catalyzed by Rubisco.

Question #33 Key: (C)BIOLOGY
04. Bioenergetics

During photosynthetic carbon fixation in the Calvin cycle, carbon dioxide functionally acts as ...

CORE CONCEPT & DERIVATION

In the reduction phase of the Calvin cycle, the carbon fixed from CO₂ undergoes enzymatic reduction by accepting electrons and hydrogen ions (protons) donated by NADPH.

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

- Carbon dioxide is first added to ribulose-1,5-bisphosphate (RuBP) by Rubisco to yield an unstable six-carbon intermediate that cleaves into 3-phosphoglycerate (3-PGA).
- In the subsequent reduction step, each molecule is phosphorylated by ATP and then accepts hydrogen atoms (protons and electrons) from NADPH.
- Because the carbon skeleton accepts protons during reduction to form carbohydrates, standard biological curricula classify CO₂ as a proton/electron acceptor.

Why other options are incorrect:

- Option A:** Carbon dioxide lacks hydrogen atoms and cannot serve as a proton donor; NADPH provides protons.
- Option B:** CO₂ gains electrons during reduction and thus acts as an electron acceptor, not an electron donor.
- Option D:** The source of O₂ released during photosynthesis is water via photolysis in PSII, not carbon dioxide (as proven by Van Niel's and Ruben's isotopic experiments).

Question #34 Key: (A)BIOLOGY
04. Bioenergetics

The direct three-carbon carbohydrate end product synthesized and exported by the Calvin cycle is...

CORE CONCEPT & DERIVATION

The primary, direct carbohydrate product exported from the Calvin cycle is the three-carbon phosphorylated triose glyceraldehyde-3-phosphate (G3P / PGAL).

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

- For every three molecules of CO₂ fixed, six molecules of G3P are produced through carbon fixation and reduction.
- Five of these G3P molecules remain within the stroma to regenerate the three consumed RuBP molecules, requiring ATP.
- The single net exported G3P molecule enters the cytosol, where pairs of trioses condense to form glucose, fructose, sucrose, or starch.

Why other options are incorrect:

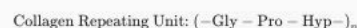
- Option B:** 3-phosphoglycerate (3-PGA) is the initial carboxylation intermediate formed when CO₂ reacts with RuBP, not the end export product.
- Option C:** 1,3-bisphosphoglycerate is a transient phosphorylated intermediate formed before reduction by NADPH.
- Option D:** Glucose is not the direct product exported from the cycle; it is synthesized downstream in the cytoplasm or stroma through condensation of exported triose phosphates.

Question #35 Key: (B)BIOLOGY
02. Biomolecules

Which of the following biomolecules is composed of amino acids?

CORE CONCEPT & DERIVATION

Collagen is a structural fibrous protein composed of polypeptide chains of amino acids arranged in a distinctive right-handed triple helix.

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

- Proteins are biological polymers synthesized from α-amino acid monomers linked together by peptide bonds.
- Collagen is the primary extracellular matrix protein in connective tissues, rich in glycine, proline, and hydroxyproline.
- Upon hydrolysis, collagen breaks down into its constituent amino acid building blocks.

Why other options are incorrect:

- Option A:** Cellulose is a polysaccharide carbohydrate composed of β-D-glucose monomers joined by β-1,4-glycosidic bonds.
- Option C:** Sucrose is a disaccharide carbohydrate composed of α-D-glucose and β-D-fructose linked by an α, β-1,2-glycosidic bond.
- Option D:** Ascorbic acid (vitamin C) is a monosaccharide-derived water-soluble organic acid, not a protein.

Question #36 Key: (C)BIOLOGY
02. Biomolecules

Hydrolysis is the chemical breakdown of a polymer into its constituent monomers through the addition of...

CORE CONCEPT & DERIVATION

Hydrolysis (hydro = water, lysis = cleavage) is a catabolic chemical reaction in which covalent bonds joining monomers are cleaved by the stoichiometric addition of a water molecule.

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

- During macromolecular synthesis, monomers are linked together through dehydration condensation reactions that release water.
- During digestion or cellular degradation, polymers are disassembled back into free monomers through the reverse process: hydrolysis.
- In this reaction, the added water molecule splits into –H and –OH, which attach to the newly separated ends of the monomers.

Why other options are incorrect:

- Option A:** A hydroxyl group alone (–OH) is a radical or ion that cannot complete bond termination without a corresponding hydrogen atom.
- Option B:** Pure hydrogen addition represents a chemical hydrogenation (reduction) reaction, not a hydrolytic cleavage.
- Option D:** Addition of nitrogen-containing functional groups represents amination or transamination, not polymer bond cleavage.

Question #37 Key: (D)BIOLOGY
02. Biomolecules

Which of the following organic compounds is NOT classified as a carbohydrate?

CORE CONCEPT & DERIVATION

Carbohydrates are defined chemically as polyhydroxy aldehydes, polyhydroxy ketones, or substances that yield such compounds upon hydrolysis; having an empirical formula of $C_n(H_2O)_n$ alone does not make a molecule a carbohydrate.

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

- Lactic acid has the molecular formula $C_3H_6O_3$, which fits the general ratio $C_n(H_2O)_n$ where $n = 3$.
- However, its chemical structure consists of a carboxylic acid functional group ($-COOH$) and a single hydroxyl group ($-OH$).
- Because it lacks the requisite multiple hydroxyl groups and carbonyl (aldehyde or ketone) functional group, it is classified as a carboxylic acid rather than a carbohydrate.

Why other options are incorrect:

- Option A:** Glucose is an aldohexose monomer with five hydroxyl groups and an aldehyde group, fitting both the empirical formula and functional definition of a carbohydrate.
- Option B:** Sucrose is a disaccharide carbohydrate composed of glucose and fructose linked by a glycosidic bond.
- Option C:** Rhamnose is a naturally occurring deoxyhexose carbohydrate (sugar) that lacks one oxygen atom, proving that not all carbohydrates strictly match the standard ratio.

Question #38 Key: (B)BIOLOGY
02. Biomolecules

Owing to its high latent heat of vaporization, water plays an essential physiological role in...

CORE CONCEPT & DERIVATION

The high latent heat of vaporization of water (approximately 2.44 kJ/g at physiological temperatures) allows organisms to lose substantial heat with minimal water loss during evaporation.

Formula / Rule / Reaction:

$$\Delta H_{\text{vap}} = 40.7 \text{ kJ/mol} \approx 2260 \text{ J/g at } 100^\circ\text{C}$$

Solution:

- Extensive intermolecular hydrogen bonding between water molecules requires a substantial amount of thermal energy to convert liquid water into vapor.
- When water evaporates from an organism's surface (such as perspiration in humans or transpiration in plants), this heat of vaporization is extracted directly from the body surface.
- This mechanism prevents overheating during vigorous metabolic activity or high environmental temperatures, acting as a cooling mechanism.

Why other options are incorrect:

- Option A:** Water's role as an excellent biological solvent arises from its high dielectric constant and permanent dipole moment, not its latent heat of vaporization.
- Option C:** Hydrophobic exclusion forces drive lipid bilayer assembly to stabilize membranes, which relates to water's polar hydrogen-bonding network in bulk liquid state.
- Option D:** Thermal insulation is provided by adipose tissue, air, or high specific heat capacity, not by heat loss during phase vaporization.

Question #39 Key: (D)BIOLOGY
01. Cell

Which of the following biological molecules does NOT contribute to the structural framework of...

CORE CONCEPT & DERIVATION

Biological membranes conform to the fluid mosaic model, composed predominantly of a phospholipid bilayer, embedded integral and peripheral proteins, cholesterol, and surface glycolipids or glycoproteins.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The core structural matrix of cellular membranes is formed by amphipathic phospholipids and glycolipids arranged in a bimolecular leaflet.
- Proteins embedded within or anchored to this bilayer include transport proteins, receptors, enzymes, and glycoproteins that constitute the protective extracellular glycocalyx.
- Nucleoproteins are structural complexes formed by nucleic acids (DNA or RNA) associated with basic proteins (such as histones or protamines), which are localized strictly within the nucleoplasm or ribonucleoprotein particles, not biological membranes.

Why other options are incorrect:

- Option A:** Glycoproteins are integral components of the plasma membrane, projecting oligosaccharide chains into the extracellular space for cell recognition and signaling.
- Option B:** Phospholipids constitute the primary structural lipid bilayer of all cellular and organelle membranes.
- Option C:** Cholesterol is an essential steroid lipid intercalated between phospholipid fatty acyl chains that modulates membrane fluidity.

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

Which of the following disaccharide molecules yields both D-glucose and D-fructose upon complet...

CORE CONCEPT & DERIVATION

Sucrose is a non-reducing disaccharide composed of an α -D-glucopyranose unit and a β -D-fructofuranose unit joined through an α, β -1,2-glycosidic linkage.

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

- Hydrolysis of sucrose cleaves the glycosidic bond bridging carbon-1 of glucose and carbon-2 of fructose.
- Because both anomeric carbons are tied up in the linkage, sucrose itself is non-reducing, but its equimolar hydrolytic products yield free glucose and fructose (invert sugar).
- This reaction is catalyzed in the digestive tract by the intestinal brush border enzyme sucrase (invertase).

Why other options are incorrect:

- Option A:** Starch is a storage homopolysaccharide composed solely of repeating α -D-glucose units linked by α -1,4 and α -1,6 glycosidic bonds; it yields only glucose upon complete hydrolysis.
- Option B:** Maltose is a disaccharide consisting of two α -D-glucose monomers linked via an α -1,4-glycosidic bond.
- Option D:** Lactose is milk sugar composed of β -D-galactose and α -D-glucose joined by a β -1,4-glycosidic bond.

Question #41 Key: (D)BIOLOGY
01. Cell

The specialized repetitive DNA sequences capping the terminal ends of eukaryotic chromosomes are...

CORE CONCEPT & DERIVATION

Telomeres are specialized non-coding nucleoprotein caps positioned at the physical ends of linear eukaryotic chromosomes that prevent end-to-end chromosomal fusion and protect coding DNA from progressive degradation.

Formula / Rule / Reaction:

Human Telomeric Repeat: 5' – TTAGGG – 3'

Solution:

- During lagging strand replication, the inability of DNA polymerase to synthesize the terminal segment following RNA primer removal results in end-replication loss.
- Telomeres consist of tandem hexanucleotide repeats bound by the shelterin protein complex, forming a protective t-loop structure.
- This cap shields chromosome termini from being mistakenly recognized as double-stranded DNA breaks by cellular DNA repair machinery.

Why other options are incorrect:

- **Option A:** Chromosomal satellites (trabants) are rounded terminal segments of chromosomes separated from the main body by a secondary constriction, not the protective terminal capping sequence itself.
- **Option B:** The kinetochore is a multi-protein disc assembled at the centromere that anchors spindle microtubules during karyokinesis.
- **Option C:** Nucleolar organizer regions (NORs) are chromosomal loops containing clusters of tandemly repeated ribosomal RNA genes that assemble the nucleolus.

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

The narrow fluid-filled extracellular space separating the presynaptic terminal from the postsy...

CORE CONCEPT & DERIVATION

A chemical synapse comprises three primary functional components: the presynaptic axon terminal, the synaptic cleft, and the postsynaptic receptive membrane.

Formula / Rule / Reaction:

Action Potential → Ca^{2+} Influx → Vesicle Exocytosis → Diffusion across Cleft (20 to 40 nm) → Receptor Activation

Solution:

- The synaptic cleft is an extracellular gap measuring approximately 20 to 40 nanometers wide.
- Because electrical current cannot jump across this fluid-filled gap, transmission relies on chemical neurotransmitters diffusing across the cleft to bind ligand-gated receptors.
- This architectural separation prevents continuous, uncontrolled electrical crosstalk between adjacent neural circuits.

Why other options are incorrect:

- **Option A:** The synaptic knob (terminal bouton) is the swollen distal extremity of an axon terminal that stores synaptic vesicles and mitochondria.
- **Option C:** Synaptic delay represents the brief physiological time interval (0.3 to 0.5 milliseconds) required for neurotransmitter exocytosis, diffusion, and receptor activation.
- **Option D:** A synaptic vesicle is a membrane-bound intracellular organelle within the presynaptic terminal that packages neurotransmitter molecules.

Question #43 Key: (B)BIOLOGY
10. Homeostasis

The neuroanatomical structure that functions as the central homeostatic thermostat regulating c...

CORE CONCEPT & DERIVATION

The hypothalamus contains central thermoreceptors in its preoptic area that continuously monitor blood temperature and integrate peripheral sensory inputs to direct physiological autonomic thermo-effector mechanisms.

Formula / Rule / Reaction:

Core Set Point $\approx 37.0^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$ —Anterior / Posterior Hypothalamus—, Sweating, Shivering, Vasomotor Tone

Solution:

- The anterior preoptic hypothalamus coordinates heat-loss mechanisms (cutaneous vasodilation and sweating) when core temperature exceeds the homeostatic set point.
- The posterior hypothalamus coordinates heat-conservation and heat-production mechanisms (cutaneous vasoconstriction, piloerection, shivering thermogenesis, and endocrine release of thyroid hormones) during hypothermia.
- Thus, the hypothalamus serves as the master thermostat of the mammalian nervous system.

Why other options are incorrect:

- **Option A:** The thalamus functions as the major sensory relay station of the brain, processing and dispatching ascending sensory signals (except olfaction) to the cerebral cortex.
- **Option C:** The pons forms a bridge connecting higher brain centers with the cerebellum and contains autonomic nuclei that regulate breathing rate (pneumotaxic and apneustic centers).
- **Option D:** The cerebellum coordinates complex somatic motor patterns, muscular tone, posture, and equilibrium.

Question #44 Key: (A)BIOLOGY
12. Nervous Coordination

A long, slender cytoplasmic extension that propagates nerve impulses away from the neuronal cel...

CORE CONCEPT & DERIVATION

Neurons are structurally polarized cells consisting of a somatodendritic compartment specialized for receiving inputs and a single elongated axon specialized for transmitting action potentials to target tissues.

Formula / Rule / Reaction:

Direction of Propagation: Dendrite → Soma → Axon Hillock → Axon → Synaptic Bouton

Solution:

- The axon arises from the axon hillock, a specialized trigger zone of the soma characterized by a high density of voltage-gated sodium channels.
- Axons can extend from a few micrometers up to over a meter in length (such as sciatic motor axons in humans).
- Its primary physiological role is the rapid, non-decremental conduction of action potentials away from the cell body toward synaptic targets.

Why other options are incorrect:

- **Option B:** Auxin (indole-3-acetic acid) is a major class of plant phytohormones regulating apical dominance, cell elongation, and tropisms.
- **Option C:** A Schwann cell is a peripheral glial support cell that wraps around axons to produce the insulating myelin sheath in the peripheral nervous system.
- **Option D:** Dendrites are short, highly branched processes that conduct graded electrical potentials toward the cell body.

Question #45 Key: (A)BIOLOGY
13. Chemical Coordination

Which of the following endocrine signaling molecules is classified chemically as a steroid hormone...

CORE CONCEPT & DERIVATION

Steroid hormones are lipophilic signaling molecules synthesized from cholesterol that cross the lipid bilayer to bind intracellular nuclear receptors and modulate gene transcription.

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

- Cortisone (and its active form cortisol) is a glucocorticoid produced by the zona fasciculata of the adrenal cortex.
- Its biochemical structure features the cyclopentanoperhydrophenanthrene (sterane) four-ring carbon skeleton characteristic of all steroid derivatives.
- It regulates gluconeogenesis, suppresses inflammatory cascades, and modulates stress responses.

Why other options are incorrect:

- **Option B:** Adrenaline (epinephrine) is a catecholamine amine hormone derived enzymatically from the amino acid L-tyrosine in the adrenal medulla.
- **Option C:** Insulin is a two-chain peptide hormone (51 amino acids linked by disulfide bonds) synthesized and secreted by pancreatic beta cells.
- **Option D:** Thyroxine (T_4) is an iodinated amino acid derivative synthesized from tyrosine residues on thyroglobulin within the thyroid gland.

Question #46 Key: (C)BIOLOGY
12. Nervous Coordination

Endogenous chemical messengers released at synaptic junctions to transmit signals from one neur...

CORE CONCEPT & DERIVATION

Neurotransmitters are specialized chemical signaling agents synthesized in neurons, stored in presynaptic vesicles, and exocytosed into the synaptic cleft upon depolarization to alter postsynaptic membrane permeability.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- When an action potential invades the axon terminal, voltage-gated calcium channels open, inducing vesicle fusion with the presynaptic active zone.
- Released neurotransmitters (such as acetylcholine, GABA, glutamate, or dopamine) diffuse across the cleft and bind to ligand-gated ion channels or G-protein coupled receptors.
- This binding produces excitatory or inhibitory postsynaptic potentials, enabling rapid inter-neuronal communication.

Why other options are incorrect:

- **Option A:** Hormones are endocrine chemical messengers secreted directly into blood vessels to act on distant target organs over prolonged time scales.
- **Option B:** Activators are allosteric or co-factor molecules that increase the catalytic velocity of specific enzymes.
- **Option D:** Enzymes are biocatalysts that accelerate chemical reaction rates by lowering activation energy without altering the equilibrium position.

Question #47 Key: (D)BIOLOGY
06. Digestion/Nutrition

Which of the following digestive enzymes exhibits an alkaline optimum pH for its catalytic acti...

CORE CONCEPT & DERIVATION

Digestive enzymes are adapted to function within specific anatomical compartments whose local chemical environments dictate their optimal ionization states and enzymatic activities.

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

- Pancreatic lipase is secreted by pancreatic acinar cells and delivered via the pancreatic duct into the lumen of the duodenum.
- Brunner's glands and pancreatic duct cells secrete abundant bicarbonate (HCO_3^-), neutralizing acidic gastric chyme to establish an alkaline pH of 7.5 to 8.5.
- Pancreatic lipase requires this alkaline environment along with bile salt emulsification to hydrolyze emulsified triglycerides efficiently.

Why other options are incorrect:

- **Option A:** Pepsin is a gastric endopeptidase that operates under strongly acidic conditions with an optimum pH of 1.5 to 2.0; it denatures irreversibly in alkaline solutions.
- **Option B:** Salivary amylase (ptyalin) acts within the mouth and has an optimum pH that is nearly neutral, operating between 6.7 and 7.0.
- **Option C:** Enterokinase (enteropeptidase) is a brush border peptidase with an optimum pH near neutrality (around 6.0 to 7.0), whereas pancreatic lipase operates efficiently in distinctly alkaline conditions up to pH 8.5.

Question #48 Key: (D)BIOLOGY
03. Enzymes

In the study of enzyme kinetics, the term 'minimum temperature' refers to the temperature at wh...

CORE CONCEPT & DERIVATION

Enzyme activity depends on thermal kinetic energy; at very low temperatures, enzymes are reversibly inactivated because molecules lack sufficient kinetic energy for effective catalytic collisions.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Unlike high temperatures which cause irreversible denaturation of tertiary protein structure, near-freezing temperatures simply render enzymes inactive due to low molecular mobility.
- The minimum temperature is defined in classic biological curricula as the lowest threshold temperature at which molecular motion provides sufficient activation energy for an inactive enzyme to become reactive.
- Above this temperature threshold, the velocity of the reaction begins to increase predictably toward the optimum temperature.

Why other options are incorrect:

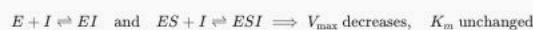
- **Option A:** Irreversible thermal denaturation occurs at maximum temperatures (typically above 55°C to 60°C in humans) due to disruption of hydrogen and hydrophobic bonds.
- **Option B:** The temperature at which an enzyme operates at its maximum velocity is designated as the optimum temperature.
- **Option C:** Enzymes do not become hyperactive at minimal temperatures; low thermal energy reduces molecular collisions.

Question #49 Key: (B)BIOLOGY
03. Enzymes

Which of the following statements correctly describes non-competitive enzyme inhibition?

CORE CONCEPT & DERIVATION

Non-competitive inhibitors bind reversibly or irreversibly to an allosteric site distinct from the active site, inducing a conformational change that reduces catalytic efficiency (decreasing $V_{\max}$) without changing substrate affinity (K_m).

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

- Because the inhibitor binds outside the catalytic cleft, it does not prevent substrate binding, meaning the enzyme-substrate-inhibitor (ESI) complex can still form.
- However, the allosteric distortion impairs transition state stabilization and catalytic turnover, rendering the active site non-functional.
- Because increasing substrate concentration cannot displace an allosteric inhibitor, the maximal velocity ($V_{\max}$) remains suppressed.

Why other options are incorrect:

- Option A:** Competing directly with substrate for the active site defines competitive inhibition, not non-competitive inhibition.
- Option C:** Malonate is a classic competitive inhibitor of succinate dehydrogenase due to its structural resemblance to succinate.
- Option D:** Overcoming inhibition by adding excess substrate is a hallmark of competitive inhibition, whereas non-competitive inhibition cannot be overcome by high substrate concentrations.

Question #50 Key: (A)BIOLOGY
06. Digestion/Nutrition

Which type of digestive enzyme would show the highest catalytic activity in your gut immediately...

CORE CONCEPT & DERIVATION

Dietary starch (amylose and amylopectin) consists of long glucose chains joined by α -1,4-glycosidic bonds that are rapidly cleaved into maltose, maltotriose, and α -limit dextrins by α -amylase.

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

- Bread is predominantly composed of complex plant starch derived from wheat flour.
- Digestion begins in the mouth via salivary amylase and continues in the duodenum via pancreatic amylase.
- These amylases attack internal α -1,4-bonds, making amylase the predominant enzyme active in breaking down starch following a carbohydrate-heavy meal.

Why other options are incorrect:

- Option B:** Erepsin is an antiquated term for a mixture of intestinal brush-border peptidases that digest small peptides into free amino acids.
- Option C:** Lactase hydrolyzes the milk disaccharide lactose into galactose and glucose; it does not digest bread starch.
- Option D:** Carboxypeptidase is a pancreatic exopeptidase that cleaves individual hydrophobic or basic amino acids from the carboxyl terminus of dietary peptides.

Question #51 Key: (D)BIOLOGY
16. Evolution

The foundational evolutionary treatise titled 'On the Origin of Species by Means of Natural Selection'...

CORE CONCEPT & DERIVATION

Charles Darwin developed and published the comprehensive theory of descent with modification powered by natural selection, providing a unified mechanistic basis for biological evolution.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Published in November 1859, Darwin's work demonstrated that individuals possessing heritable variations suited to their environment enjoy differential survival and reproductive success.
- Over generations, advantageous traits accumulate within populations, producing progressive adaptations and speciation.
- This replaced older concepts of immutable biological species with an empirical model of common ancestry.

Why other options are incorrect:

- Option A:** Jean-Baptiste Lamarck proposed the early hypothesis of inheritance of acquired characteristics (use and disuse), which lacked a mechanism of heritable natural selection.
- Option B:** Carolus Linnaeus established formal binomial nomenclature and hierarchical classification, viewing species as fixed creations.
- Option C:** G. H. Hardy and Wilhelm Weinberg formulated the mathematical principle of genetic equilibrium in non-evolving populations.

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

Which of the following is NOT a direct immunological mechanism of action carried out by circula...

CORE CONCEPT & DERIVATION

Antibodies (immunoglobulins) are non-living, non-metabolic soluble protein effectors that neutralize pathogens, fix complement, and enhance phagocytosis, but do not produce or secrete signaling cytokines.

Formula / Rule / Reaction:

Effector Functions of Antibodies: Neutralization + Agglutination + Precipitation + Complement

Solution:

- Antibodies physically bind antigenic determinants via their variable Fab regions, blocking viral attachment (neutralization), cross-linking particles (agglutination), or rendering soluble toxins insoluble (precipitation).
- Their constant Fc regions bind to phagocyte Fc receptors, enhancing phagocytosis (opsonization).
- Cytokines (such as interleukins and interferons) are peptide signaling molecules synthesized and secreted by living immune cells (especially helper T cells, macrophages, and dendritic cells), not by antibodies themselves.

Why other options are incorrect:

- Option A:** Neutralization is a primary mechanism whereby antibodies coat bacterial exotoxins or viral spikes, blocking their attachment to cellular receptors.
- Option B:** Precipitation occurs when polyvalent antibodies cross-link soluble antigens into large insoluble complexes that are cleared by phagocytes.
- Option D:** Opsonization occurs when the Fc domains of bound IgG molecules interact with Fc receptors on macrophages and neutrophils, accelerating phagocytic engulfment.

Question #53 Key: (C)BIOLOGY
04. Bioenergetics

Magnesium is an essential mineral nutrient in green plants primarily required for the biosynthe...

CORE CONCEPT & DERIVATION

A single divalent magnesium ion (Mg^{2+}) coordinates at the center of the porphyrin-like tetrapyrrole ring in all chlorophyll molecules, making it essential for light harvesting and photosynthetic charge separation.

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

- Magnesium serves as the core coordinating metal ion in both chlorophyll *a* and chlorophyll *b*, held by four nitrogen atoms within the chlorin macrocycle.
- This coordination stabilizes the electronic structure, allowing absorption of red and blue light wavelengths while exciting electrons for photochemistry.
- Magnesium deficiency in plants impairs chlorophyll synthesis, producing interveinal chlorosis in mature leaves.

Why other options are incorrect:

- **Option A:** Proteins require carbon, hydrogen, oxygen, nitrogen, and sulfur (for cysteine and methionine); magnesium does not form a covalent part of polypeptide chains.
- **Option B:** Plant lipids are composed of glycerol and fatty acids (hydrocarbons with ester linkages) and do not contain magnesium.
- **Option D:** While Mg^{2+} acts as an essential inorganic cofactor for kinases and Rubisco, the structural backbone of enzyme molecules consists of amino acids rather than magnesium complexes.

Question #54 Key: (C)BIOLOGY
09. Respiration / Gaseous Exchange

Which of the following anatomical divisions of the human respiratory tract completely lacks sup...

CORE CONCEPT & DERIVATION

As the respiratory conducting zone branches into narrower tubes, the supportive hyaline cartilaginous plates of the bronchi diminish and disappear completely once the airways reach a diameter of less than 1 mm, defining the bronchioles.

Formula / Rule / Reaction:

Larynx (Cartilage) → Trachea (C-rings) → Bronchi (Plates) → **Bronchioles (No Cartilage, Smooth Muscle Only)**

Solution:

- Bronchioles are small conducting tubes branching from tertiary bronchi with diameters under 1 mm.
- Their walls lack cartilage plates and submucosal glands, consisting instead of an epithelial lining surrounded by a circular layer of smooth muscle.
- Because they lack rigid cartilage, bronchioles are susceptible to bronchoconstriction, as seen in acute asthma attacks.

Why other options are incorrect:

- **Option A:** The larynx is reinforced by nine framework cartilages (thyroid, cricoid, epiglottis, and paired arytenoid, corniculate, and cuneiform cartilages).
- **Option B:** The trachea is reinforced by 16 to 20 anterior C-shaped hyaline cartilage rings that keep the airway patent during pressure shifts.
- **Option D:** Primary, secondary, and tertiary bronchi contain irregular hyaline cartilage plates embedded within their fibrous adventitia.

Question #55 Key: (B)BIOLOGY
06. Digestion/Nutrition

The enzymatic portion of gastric juice, containing the proenzyme pepsinogen, is secreted by whi...

CORE CONCEPT & DERIVATION

Gastric chief (peptic or zymogenic) cells reside in the basal regions of gastric oxyntic glands and synthesize and release pepsinogen, the inactive zymogen precursor to the proteolytic enzyme pepsin.

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

- Chief cells possess extensive rough endoplasmic reticulum, prominent Golgi complexes, and apical zymogen granules loaded with pepsinogen.
- Upon secretagogue stimulation (acetylcholine and gastrin), they release pepsinogen into the gastric pits via exocytosis.
- Contact with hydrochloric acid in the stomach lumen cleaves an inhibitory peptide sequence, exposing pepsin's active site to initiate dietary protein digestion.

Why other options are incorrect:

- **Option A:** Oxyntic (parietal) cells secrete hydrochloric acid (HCl) to acidify gastric juice and intrinsic factor for ileal vitamin B_{12} absorption.
- **Option C:** Mucous neck cells secrete alkaline mucin and bicarbonate to form the protective gastric mucosal barrier that prevents self-digestion.
- **Option D:** Enteroendocrine cells (such as G cells) secrete regulatory peptide hormones (such as gastrin) into the local capillary circulation rather than digestive enzymes.

Question #56 Key: (B)PHYSICS
05. Waves

The horizontal distance traversed by a periodic wave during the time required to complete one f...

CORE CONCEPT & DERIVATION

The wavelength is the fundamental spatial period of a wave, defined as the distance between two consecutive points in identical phase of oscillation along the direction of wave propagation.

Formula / Rule / Reaction:

$$\lambda = vT = \frac{v}{f}$$

Solution:

- During the duration of one complete temporal oscillation (the period, T), the wave energy advances through space at wave speed v .
- The linear spatial distance covered during this single cycle equals the wavelength (λ).
- This distance is measured from crest to consecutive crest, or trough to consecutive trough, in transverse waves.

Why other options are incorrect:

- **Option A:** Frequency (f) is a temporal rate representing the number of complete vibrational cycles occurring per unit time, measured in Hertz (s^{-1}).
- **Option C:** Amplitude is the maximum spatial displacement of an oscillating particle from its central equilibrium position.
- **Option D:** Time period (T) is the temporal duration required for one complete oscillation, measured in seconds.

Question #57 Key: (D)PHYSICS
05. Waves

If the period of oscillation of a mass [Formula] suspended from an ideal spring is [Formula], ...

CORE CONCEPT & DERIVATION

The period of oscillation of an ideal mass-spring simple harmonic oscillator is directly proportional to the square root of the oscillating mass.

Formula / Rule / Reaction:

$$T = 2\pi\sqrt{\frac{m}{k}} \Rightarrow T \propto \sqrt{m}$$

Solution:

- For the initial mass M , the period of oscillation is:

$$T_1 = 2\pi\sqrt{\frac{M}{k}} = 2 \text{ s}$$

- When the mass is replaced by $4M$, the new period T_2 is given by:

$$T_2 = 2\pi\sqrt{\frac{4M}{k}} = \sqrt{4} \times (2\pi\sqrt{\frac{M}{k}}) = 2 \times T_1$$

- Substituting the given value of $T_1 = 2 \text{ s}$:

$$T_2 = 2 \times 2 \text{ s} = 4 \text{ s}$$

Why other options are incorrect:

- Option A:** 1 s would result if the mass were reduced to one-fourth of its initial value, because $\sqrt{1/4} = 1/2$.
- Option B:** 2 s represents the unchanged period, which would occur only if the mass were kept constant.
- Option C:** 3 s does not match the square root dependency of the simple harmonic oscillator equation.

Question #58 Key: (A)PHYSICS
05. Waves

The psychological perception of the loudness of a sound wave is most directly related to which...

CORE CONCEPT & DERIVATION

Loudness is the subjective auditory sensation that corresponds directly to the physical intensity (energy transmitted per second per unit area) and amplitude of the acoustic pressure wave.

Formula / Rule / Reaction:

$$I = 2\pi^2\rho v f^2 A^2 \Rightarrow I \propto A^2, \quad \beta = 10 \log_{10} \left(\frac{I}{I_0} \right)$$

Solution:

- Sound intensity is defined as the acoustic power transported by the sound wave per unit area perpendicular to the direction of propagation.
- As the amplitude of the vibrating medium increases, greater pressure fluctuations impact the tympanic membrane, increasing physical intensity.
- The human auditory system perceives this increased mechanical wave energy as greater loudness, modeled logarithmically in decibels.

Why other options are incorrect:

- Option B:** The frequency of a sound wave governs the subjective perception of pitch, not loudness.
- Option C:** Wavelength is the spatial cycle distance, inversely related to frequency, and does not determine perceived loudness.
- Option D:** The speed of sound is an intrinsic property of the elasticity and density of the transmitting medium.

Question #59 Key: (D)PHYSICS
05. Waves

The increase in the speed of sound in dry air for each degree Celsius rise in temperature above...

CORE CONCEPT & DERIVATION

The speed of sound in an ideal gas is directly proportional to the square root of its absolute temperature, which simplifies via binomial expansion to a linear increase of 0.61 m s^{-1} per degree Celsius.

Formula / Rule / Reaction:

$$v_t = v_0 \sqrt{\frac{T_0 + t}{T_0}} = v_0 \left(1 + \frac{t}{273}\right)^{1/2} \approx v_0 + \left(\frac{v_0}{546}\right)t = v_0 + 0.61t$$

Solution:

- At 0°C (273 K), the speed of sound in dry air is $v_0 \approx 332 \text{ m s}^{-1}$.
- Applying the binomial expansion for small temperature changes:

$$\Delta v = \frac{v_0}{2 \times 273} \times t = \frac{332}{546}t \approx 0.61t \text{ m s}^{-1}$$
- Therefore, for every 1°C rise in temperature above 0°C , sound velocity in air increases by approximately 0.61 m s^{-1} .

Why other options are incorrect:

- Option A:** 0.40 m s^{-1} underestimates the expansion coefficient because it assumes a much lower baseline speed of sound.
- Option B:** 0.51 m s^{-1} does not match the thermodynamic ratio derived from Laplace's correction for air.
- Option C:** 0.81 m s^{-1} overestimates the temperature coefficient for air under standard atmospheric conditions.

Question #60 Key: (D)PHYSICS
07. Thermodynamics

The first law of thermodynamics is a direct mathematical manifestation of the fundamental law of...

CORE CONCEPT & DERIVATION

The first law of thermodynamics extends the principle of conservation of energy to thermodynamic systems, asserting that energy cannot be created or destroyed, only transformed between heat, work, and internal energy.

Formula / Rule / Reaction:

$$\Delta U = Q - W \quad \text{or} \quad Q = \Delta U + W$$

Solution:

- When an amount of heat Q is supplied to an isolated or closed thermodynamic system, it is conserved without any net gain or loss of total energy.
- Part of this energy input increases the internal kinetic and potential energy of the gas particles (ΔU), while the remaining fraction is expended as macroscopic mechanical boundary work ($W = P\Delta V$).
- Because every unit of added thermal energy is accounted for by the sum of work performed and internal energy change, the first law represents conservation of energy.

Why other options are incorrect:

- Option A:** Conservation of electric charge states that net charge in an isolated system remains constant, which forms the basis of Kirchhoff's Current Law.
- Option B:** Conservation of mass applies to classical chemical reactions where mass cannot be created or destroyed, not the thermodynamic energy balance.
- Option C:** Conservation of linear momentum applies to collision mechanics where net external force is zero, not the interconversion of heat and work.

Question #61 Key: (C)PHYSICS
07. Thermodynamics

A thermodynamic process in which the pressure of the working gas remains constant throughout th...

CORE CONCEPT & DERIVATION

An isobaric process is an equilibrium thermodynamic transformation occurring at constant hydrostatic pressure ($\Delta P = 0$), during which heat exchanged changes both internal energy and mechanical work.

Formula / Rule / Reaction:

$$P = \text{constant}, \quad \Delta P = 0 \implies W = P\Delta V = P(V_2 - V_1)$$

Solution:

- The term isobaric is derived from Greek 'iso' (equal) and 'baros' (weight/pressure).
- In an isobaric process, the volume of a gas expands or contracts in direct proportion to its absolute temperature according to Charles's law ($V/T = \text{constant}$).
- Because pressure is constant, work performed during volume change appears on a P - V indicator diagram as a horizontal line with area $P(V_2 - V_1)$.

Why other options are incorrect:

- Option A:** An isochoric (isovolumetric) process occurs at constant volume ($\Delta V = 0$), resulting in zero boundary work done ($W = 0$).
- Option B:** An adiabatic process occurs without heat exchange between the system and its surroundings ($Q = 0$).
- Option D:** An isothermal process occurs at constant absolute temperature ($\Delta T = 0$), meaning internal energy for an ideal gas remains unchanged ($\Delta U = 0$).

Question #62 Key: (A)PHYSICS
08. Electrostatics

The electrostatic potential energy stored in a charged parallel plate capacitor of capacitance ...

CORE CONCEPT & DERIVATION

Charging a capacitor requires electrical work against the accumulating electrostatic repulsive potential, storing energy within the electric field between the plates.

Formula / Rule / Reaction:

$$E = \int_0^Q V(q) dq = \int_0^Q \frac{q}{C} dq = \frac{Q^2}{2C} = \frac{1}{2}QV = \frac{1}{2}CV^2$$

Solution:

- As charge q builds up on the plates, the potential difference rises linearly according to $V = q/C$.
 - Integrating this incremental work from zero charge to final charge Q yields:
- $$W = \frac{1}{2} \frac{Q^2}{C}$$
- Using the relation $Q = CV$, substituting for charge gives the stored energy:

$$E = \frac{1}{2} CV^2$$

Why other options are incorrect:

- Option B:** $2CV^2$ is four times too large due to omitting the integration factor of one-half.
- Option C:** CV^2 represents the total energy delivered by the charging battery ($Q \times V$), of which half is dissipated as heat in the circuit resistance during charging.
- Option D:** $\frac{1}{2}C^2V$ is dimensionally incorrect for energy.

Question #63 Key: (C)PHYSICS
08. Electrostatics

Electric field intensity at a given point in space is defined physically as the:

CORE CONCEPT & DERIVATION

Electric field intensity ($\mathbf{E}$) is a vector field representing the electrostatic Coulomb force exerted per unit positive test charge placed at that location.

Formula / Rule / Reaction:

$$\mathbf{E} = \lim_{q_0 \rightarrow 0} \frac{\mathbf{F}}{q_0}, \quad \text{Unit: } \text{N C}^{-1} \text{ or } \text{V m}^{-1}$$

Solution:

- An electric charge alters the electrical properties of the surrounding space, creating an electric field.
- To measure this field strength without disturbing the source charge configuration, an infinitesimally small positive test charge q_0 is used.
- The electric field intensity is calculated as the ratio of electrostatic vector force $\mathbf{F}$ to test charge q_0 .

Why other options are incorrect:

- Option A:** Force experienced per unit mass defines gravitational field strength ($\mathbf{g} = \mathbf{F}/m$), not electric field intensity.
- Option B:** Force experienced per unit magnetic pole defines magnetic field strength in classical magnetostatics.
- Option D:** Work done per unit positive charge in bringing a test charge from infinity to a point defines electric potential ($V = W/q_0$), a scalar quantity.

Question #64 Key: (A)PHYSICS
08. Electrostatics

Which of the following electronic components stores energy predominantly in the form of an elec...

CORE CONCEPT & DERIVATION

A capacitor stores electrical energy by accumulating equal and opposite charges on separated conducting plates, establishing an internal electrostatic field.

Formula / Rule / Reaction:

$$u_E = \frac{1}{2} \epsilon_0 \epsilon_r E^2 \quad (\text{Energy Density in Electric Field})$$

Solution:

- When a direct current voltage source is connected across a capacitor, electrons transfer from one plate to the other until the potential difference matches the source.
- This charge separation sets up a uniform electric field within the dielectric between the plates.
- The potential energy is stored within this polarized dielectric field, ready for rapid discharge into a load.

Why other options are incorrect:

- Option B:** A simple conductor allows electric charges to flow freely; it does not store significant electrical potential energy unless configured as a capacitor.
- Option C:** An inductor stores energy dynamically in a magnetic field generated by current flowing through its coils ($U = \frac{1}{2}LI^2$), not an electrostatic field.
- Option D:** A generator is an electromechanical device that converts mechanical energy into alternating or direct electrical current, not an energy storage device.

Question #65 Key: (C)PHYSICS
09. Current Electricity

The magnitude of the electric current through a metallic conductor is directly proportional to...

CORE CONCEPT & DERIVATION

Ohm's law describes linear ohmic conduction in metals, where drift velocity and current are directly proportional to applied electric field and voltage at constant temperature.

Formula / Rule / Reaction:

$$I \propto V \implies V = IR \quad (\text{when } T = \text{constant})$$

Solution:

- In metallic conductors, current density is related to the electric field by $\mathbf{J} = \sigma \mathbf{E}$, where conductivity σ depends on temperature-dependent electron-lattice scattering.
- Macroscopically, integrating over the conductor's geometry yields $V = IR$.
- If temperature changes, increased thermal vibrations alter resistance R , causing deviations from this linear relationship.

Why other options are incorrect:

- Option A:** Joule's law of heating describes the rate of thermal energy generation in a resistor as proportional to current squared: $H = I^2 R t$.
- Option B:** Gauss's law relates total electric flux emerging through a closed Gaussian surface to enclosed net charge: $\Phi = Q_{\text{enc}} / \epsilon_0$.
- Option D:** Ampere's circuital law relates the line integral of magnetic field around a closed loop to the enclosed electric current: $\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 I_{\text{enc}}$.

Question #66 Key: (A)PHYSICS
13. Electronics

The electrical resistance of a pure metallic conductor increases with an:

CORE CONCEPT & DERIVATION

Pure metals possess a positive temperature coefficient of resistance ($\alpha > 0$), meaning their electrical resistance rises with increasing temperature due to enhanced electron-phonon scattering.

Formula / Rule / Reaction:

$$R_t = R_0(1 + \alpha t) \quad \text{where } \alpha = \frac{R_t - R_0}{R_0 t} > 0$$

Solution:

- Conduction in metals is carried by free valence electrons moving through a periodic lattice of positive metallic cations.
- As temperature rises, thermal energy increases the vibrational amplitude of lattice ions around their equilibrium positions.
- This larger effective scattering cross-section increases the frequency of collisions with drifting conduction electrons, shortening relaxation time τ and increasing electrical resistance.

Why other options are incorrect:

- Option B:** Moderate changes in hydrostatic pressure have negligible impact on metal lattice spacing and electrical resistance.
- Option C:** Decreasing temperature reduces lattice vibrations, decreasing resistance until reaching residual resistance near absolute zero (or superconductivity).
- Option D:** Decreasing pressure has no significant effect on the electrical resistivity of solid metallic conductors.

Question #67 Key: (D)PHYSICS
10. Electromagnetism

The magnetic field intensity [Formula] at a radial distance [Formula] inside a long, straight c...

CORE CONCEPT & DERIVATION

According to Ampere's circuital law, the magnetic field inside a uniform current-carrying cylindrical conductor of radius R increases linearly with radial distance r from the central longitudinal axis.

Formula / Rule / Reaction:

$$\oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 I_{\text{enc}} \implies B(2\pi r) = \mu_0 \left(I \frac{\pi r^2}{\pi R^2} \right) \implies B = \left(\frac{\mu_0 I}{2\pi R^2} \right) r \implies B \propto r$$

Solution:

- Construct an interior circular Amperian loop of radius $r \leq R$ concentric with the wire axis.
- Because current is uniformly distributed across cross-sectional area πR^2 , the fraction of current enclosed within radius r is $I_{\text{enc}} = I(r^2/R^2)$.
- Applying Ampere's law gives:

$$B(2\pi r) = \mu_0 I \frac{r^2}{R^2} \implies B = \frac{\mu_0 I}{2\pi R^2} r$$
- Thus, inside the conductor, B is directly proportional to radial distance r , reaching a maximum at the surface $r = R$.

Why other options are incorrect:

- Option A:** B varies inversely with r ($B \propto 1/r$) outside the wire ($r \geq R$), not inside the wire.
- Option B:** Magnetic field varies inversely with r^2 near magnetic dipoles or in Coulomb-like analogies, not inside a uniform wire.
- Option C:** The enclosed current varies with r^2 , but dividing by the loop perimeter ($2\pi r$) makes B depend linearly on r , not r^2 .

Question #68 Key: (A)PHYSICS
10. Electromagnetism

The magnetic flux passing through a plane surface of area vector [Formula] immersed in a uniform...

CORE CONCEPT & DERIVATION

Magnetic flux (Φ_B) is defined as the scalar dot product of the magnetic field vector $\mathbf{B}$ and the area vector $\mathbf{A}$, which points perpendicular to the surface.

Formula / Rule / Reaction:

$$\Phi_B = \mathbf{B} \cdot \mathbf{A} = BA \cos \theta$$

Solution:

- The area vector $\mathbf{A}$ is directed normal (perpendicular) to the plane of the surface.
- When the magnetic field lines run parallel to the area vector (perpendicular to the physical surface), the angle θ is 0° .
- Because $\cos(0^\circ) = 1$ is the maximum possible value of the cosine function:

$$\Phi_{\text{max}} = BA(1) = BA$$
- Therefore, maximum flux crosses the surface when $\theta = 0^\circ$.

Why other options are incorrect:

- Option B:** When $\theta = 90^\circ$, the magnetic field is perpendicular to the area vector (parallel to the surface plane), yielding $\Phi = BA \cos(90^\circ) = 0$.
- Option C:** At 45° , the flux is reduced to $BA \cos(45^\circ) = \frac{BA}{\sqrt{2}} \approx 0.707 BA$.
- Option D:** At 180° , the flux has maximum magnitude but is negative ($\Phi = -BA$), indicating lines entering the opposite surface face.

Question #69 Key: (B)PHYSICS
11. Electromagnetic Induction

Lenz's law of electromagnetic induction is a direct consequence of the universal law of conserv...

CORE CONCEPT & DERIVATION

Lenz's law states that an induced electromotive force always produces a current whose magnetic field opposes the original change in magnetic flux that generated it, conforming to conservation of energy.

Formula / Rule / Reaction:

$$\mathcal{E} = -N \frac{\Delta \Phi_B}{\Delta t}$$

Solution:

- When a magnet's north pole approaches a closed conducting loop, the induced current flows counter-clockwise to produce an opposing north pole face.
- An external agent must perform mechanical work against this magnetic repulsive force to keep moving the magnet closer.
- This mechanical work is converted directly into electrical energy and thermal Joule heat in the loop.
- If the induced field instead aided the flux change, the magnet would accelerate spontaneously without energy input, violating conservation of energy.

Why other options are incorrect:

- Option A:** Conservation of mass governs matter conservation in chemical systems and does not determine induced current directions.
- Option C:** Conservation of charge accounts for the constancy of net coulombs in closed circuits, not the opposing polarity of induced EMFs.
- Option D:** Conservation of momentum governs mechanical impulse and collisions, rather than flux opposition in electromagnetic induction.

Question #70 Key: (A)PHYSICS
10. Electromagnetism

In Fleming's right-hand generator rule, the thumb points in the direction of the:

CORE CONCEPT & DERIVATION

Fleming's right-hand rule determines the direction of induced current in a straight electrical conductor moving through an external magnetic field.

Formula / Rule / Reaction:

F (Thumb), **B** (Forefinger), **I** (Middle Finger)

Solution:

- Extend the thumb, forefinger (index finger), and middle finger of the right hand mutually perpendicular to one another.
- The forefinger points along the external magnetic field (**F**).
- The thumb points in the direction of mechanical motion or applied force on the conductor.
- The central (middle) finger indicates the direction of the resulting induced current (**I**).

Why other options are incorrect:

- Option B:** The forefinger (index finger) points in the direction of the magnetic field vector.
- Option C:** The middle (second) finger indicates the direction of the induced current.
- Option D:** Fleming's rule specifically relates conductor velocity, magnetic field, and induced current; electric field direction is not indicated by the thumb.

Question #71 Key: (C)PHYSICS
11. Electromagnetic Induction

An electrical transformer operates on the physical principle of:

CORE CONCEPT & DERIVATION

A transformer transfers alternating electrical energy between two isolated circuits via mutual electromagnetic induction linked through a shared ferromagnetic core.

Formula / Rule / Reaction:

$$\mathcal{E}_s = -M \frac{\Delta I_p}{\Delta t}, \quad \frac{V_s}{V_p} = \frac{N_s}{N_p}$$

Solution:

- Alternating current flowing through the primary winding produces a continuously time-varying magnetic flux in the laminated iron core.
- This alternating magnetic flux links through the turns of the secondary winding.
- By Faraday's and Henry's law of mutual induction, this changing mutual flux induces an alternating electromotive force across the secondary terminals without physical electrical connection.

Why other options are incorrect:

- Option A:** Half-wave rectification is a conversion process using diodes to pass only one half-cycle of alternating current.
- Option B:** Self-induction is the phenomenon where a changing current in a coil induces an opposing back-EMF within that same coil.
- Option D:** Full-wave rectification uses bridge diodes to convert both positive and negative AC half-cycles into pulsating direct current.

Question #72 Key: (A)PHYSICS
13. Electronics

A semiconductor electronic device primarily used to convert alternating current (AC) into direct...

CORE CONCEPT & DERIVATION

A rectifier is an electrical circuit configuration composed of one or more semiconductor p-n junction diodes that permits current flow in one direction, converting bidirectional AC into unidirectional DC.

Formula / Rule / Reaction:

$$\text{AC Input } (V_0 \sin \omega t) \xrightarrow{\text{Rectifier (Diodes)}} \text{Pulsating DC Output}$$

Solution:

- Because a p-n junction diode conducts with low resistance during forward bias and blocks conduction during reverse bias, it acts as a one-way electrical check valve.
- Arranged in half-wave or full-wave bridge topologies, diodes convert alternating voltage waveforms into unidirectional direct current waveforms.
- Circuits that perform this conversion are designated as rectifiers.

Why other options are incorrect:

- Option B:** A transistor is a three-terminal semiconductor device used for electrical signal amplification or digital electronic switching.
- Option C:** A capacitor stores electrostatic field energy and acts as a filtering component to smooth ripple voltage, but does not rectify current by itself.
- Option D:** An inductor stores energy in a magnetic field and opposes high-frequency changes in alternating current, serving as an inductive choke rather than a rectifier.

Question #73 Key: (B)PHYSICS
13. Electronics

The electrical process of converting alternating current (AC) into unidirectional direct current...

CORE CONCEPT & DERIVATION

Rectification is the unit electrical operation in which an alternating waveform of zero average value is converted into a unidirectional waveform with a non-zero average DC component.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Alternating current periodically reverses its direction and polarity over time.
- Using asymmetric non-linear conducting elements (p-n junction diodes), rectification blocks or inverts negative half-cycles.
- The resulting unidirectional pulsating output can then be smoothed by capacitor filter circuits to power DC electronics.

Why other options are incorrect:

- **Option A:** Amplification is the process of increasing the power, voltage, or current amplitude of an electrical input signal using an active device like a transistor.
- **Option C:** Magnification is an optical parameter defined as the ratio of image size to object size produced by lenses or mirrors.
- **Option D:** Resolution is an optical term denoting the minimum distance between two distinct points at which they can still be distinguished as separate entities.

Question #74 Key: (B)PHYSICS
16. Nuclear Physics

In radiological physics, the SI unit of absorbed radiation dose, the Gray (Gy), is defined as:

CORE CONCEPT & DERIVATION

The Gray (Gy) is the International System of Units (SI) measure of absorbed ionizing radiation dose, defined as the absorption of one joule of radiation energy per kilogram of matter.

Formula / Rule / Reaction:

$$1 \text{ Gy} = 1 \text{ J kg}^{-1} = 100 \text{ rad}$$

Solution:

- Absorbed dose measures the energy deposited in biological tissue by ionizing radiation per unit mass of the irradiated tissue.
- Mathematically, $D = E/m$, where E is radiation energy absorbed in joules and m is target mass in kilograms.
- Therefore, the unit is joules per kilogram, expressed as 1 J kg^{-1} .

Why other options are incorrect:

- **Option A:** 1 J kg represents the product of energy and mass, which is dimensionally incorrect for radiation dose.
- **Option C:** $1 \text{ J}^{-1} \text{ kg}$ is the reciprocal of specific energy absorption and has no physical meaning in dosimetry.
- **Option D:** $1 \text{ J}^{-1} \text{ kg}^{-1}$ is dimensionally invalid.

Question #75 Key: (D)PHYSICS
16. Nuclear Physics

A sample containing [Formula] of a radioactive isotope decays such that only [Formula] remains ...

CORE CONCEPT & DERIVATION

Radioactive decay obeys exponential first-order kinetics, in which the mass of an undecayed radioisotope halves after each successive half-life interval.

Formula / Rule / Reaction:

$$N(t) = N_0 \left(\frac{1}{2}\right)^n, \quad n = \frac{t}{T_{1/2}}$$

Solution:

- Determine the number of half-lives n required to reduce the initial mass $N_0 = 32 \text{ g}$ down to final mass $N(t) = 2 \text{ g}$:

$$\frac{N(t)}{N_0} = \frac{2 \text{ g}}{32 \text{ g}} = \frac{1}{16} = \left(\frac{1}{2}\right)^4$$

- Equating powers gives $n = 4$ half-lives.
- Because total elapsed time is $t = 60$ days, the half-life $T_{1/2}$ is:

$$T_{1/2} = \frac{t}{n} = \frac{60 \text{ days}}{4} = 15 \text{ days}$$

Why other options are incorrect:

- **Option A:** 2 days would mean $60/2 = 30$ half-lives, leaving negligible trace amounts of the isotope.
- **Option B:** 6 days corresponds to $60/6 = 10$ half-lives, which would reduce the mass to $32/2^{10} = 0.03125 \text{ g}$.
- **Option C:** 10 days corresponds to 6 half-lives, which would reduce the mass to $32/2^6 = 0.5 \text{ g}$.

Question #76 Key: (A)PHYSICS
02. Force & Motion

An elastic collision is defined physically as an isolated interaction in which:

CORE CONCEPT & DERIVATION

In classical mechanics, an elastic collision is an encounter between two or more bodies wherein no net kinetic energy is converted into non-mechanical forms (such as thermal dissipation, acoustic waves, or permanent plastic deformation).

Formula / Rule / Reaction:

$$\sum \mathbf{p}_i = \sum \mathbf{p}_f \quad \text{and} \quad \sum \frac{1}{2} m_i v_i^2 = \sum \frac{1}{2} m_f v_f^2$$

Solution:

- Because no external net force acts on the colliding system, total linear momentum is rigorously conserved in every isolated collision (elastic or inelastic).
- In a perfectly elastic collision, the repulsive interactions during contact are completely conservative, meaning mechanical strain energy is fully restored back into kinetic energy.
- Consequently, both total linear momentum and total kinetic energy remain constant before, during, and after the impact.

Why other options are incorrect:

- **Option B:** If kinetic energy is conserved in a mechanical interaction without conservative potential changes, total mechanical energy is necessarily conserved.
- **Option C:** Momentum conservation accompanied by kinetic energy loss defines an inelastic collision.
- **Option D:** Linear momentum is always conserved in any isolated physical system lacking external impulses.

Question #77 Key: (B)PHYSICS
02. Force & Motion

The time rate of change of linear velocity of a moving particle is defined as:

CORE CONCEPT & DERIVATION

Linear acceleration is the kinematic vector quantity describing the first derivative of velocity with respect to time.

Formula / Rule / Reaction:

$$\mathbf{a} = \lim_{\Delta t \rightarrow 0} \frac{\Delta \mathbf{v}}{\Delta t} = \frac{d\mathbf{v}}{dt}, \quad \text{Unit: m s}^{-2}$$

Solution:

- Velocity is a vector quantity possessing both magnitude (speed) and directional orientation.
- Any change in either the speed of the body or its direction of motion over an interval of time results in non-zero acceleration.
- Dividing the differential change in velocity by the time interval yields the instantaneous acceleration vector.

Why other options are incorrect:

- **Option A:** Force is the product of mass and acceleration ($\mathbf{F} = m\mathbf{a}$), representing the time rate of change of linear momentum ($d\mathbf{p}/dt$).
- **Option C:** Power is the time rate of performing work or transferring energy ($P = dW/dt$).
- **Option D:** Energy is a scalar measure of a system's capacity to do work.

Question #78 Key: (B)PHYSICS
02. Force & Motion

In ideal projectile motion launched from horizontal ground in the absence of aerodynamic resist...

CORE CONCEPT & DERIVATION

The horizontal range of an unguided ballistic projectile launched across level terrain depends sinusoidally on twice the launch angle with respect to the horizontal plane.

Formula / Rule / Reaction:

$$R = \frac{v_0^2 \sin(2\theta)}{g}$$

Solution:

- For a fixed initial launch velocity v_0 and gravitational acceleration g , the range R varies directly with the trigonometric factor $\sin(2\theta)$.
- The sine function attains its theoretical maximum of 1 when its argument equals 90° :
$$2\theta = 90^\circ \implies \theta = 45^\circ$$
- At 45° , the launch velocity divides equally into horizontal and vertical components ($v_x = v_y = v_0/\sqrt{2}$), optimizing time of flight against horizontal velocity to maximize distance.

Why other options are incorrect:

- **Option A:** At 30° , $\sin(2 \times 30^\circ) = \sin(60^\circ) = \frac{\sqrt{3}}{2} \approx 0.866$, giving approximately 86.6% of maximum range.
- **Option C:** At 60° , $\sin(2 \times 60^\circ) = \sin(120^\circ) = \frac{\sqrt{3}}{2} \approx 0.866$, which yields the same submaximal range as 30° .
- **Option D:** At 90° , the projectile is fired straight upward; $\sin(180^\circ) = 0$, resulting in zero horizontal range.

Question #79 Key: (D)PHYSICS
02. Force & Motion

Regarding Newton's third law of motion and action-reaction force pairs, which of the following...

CORE CONCEPT & DERIVATION

Newton's third law states that whenever one body exerts a force on a second body, the second body exerts an equal and opposite force on the first; because these forces act on separate bodies, they can never cancel each other out.

Formula / Rule / Reaction:

$$\mathbf{F}_{AB} = -\mathbf{F}_{BA} \quad (\text{acting simultaneously on bodies } B \text{ and } A)$$

Solution:

- Forces can cancel out to establish translational static equilibrium ($\sum \mathbf{F} = 0$) if and only if they act concurrently on the exact same body.
- Action and reaction forces act on two completely different interacting bodies (force $\mathbf{F}_{AB}$ acts on body B , while $\mathbf{F}_{BA}$ acts on body A).
- Because they act on distinct free-body diagrams, they cannot cancel each other out.

Why other options are incorrect:

- **Option A:** This statement is true: action-reaction pairs must share the same physical nature (both gravitational, both electrostatic, or both contact normal forces).
- **Option B:** This statement is true: action and reaction forces are strictly collinear and act along the identical line of interaction joining the two bodies.
- **Option C:** This statement is true: by definition, action and reaction never act on the same body, which is precisely why they cannot cancel out.

Question #80 Key: (D)PHYSICS
02. Force & Motion

Two buses traveling along straight parallel lanes at speeds of [Formula] and [Formula] respectively...

CORE CONCEPT & DERIVATION

The relative velocity of an object A with respect to an object B is the vector difference between their individual ground velocities.

Formula / Rule / Reaction:

$$\mathbf{v}_{A/B} = \mathbf{v}_A - \mathbf{v}_B$$

Solution:

- Assign a 1D coordinate system where the forward direction of bus A is positive: $v_A = +100 \text{ km h}^{-1}$.
- Because bus B moves in the opposite direction, its ground velocity vector is negative: $v_B = -80 \text{ km h}^{-1}$.
- The velocity of bus A relative to bus B is:
$$v_{A/B} = v_A - v_B = 100 - (-80) = 100 + 80 = 180 \text{ km h}^{-1}$$
- Passengers on either bus observe the other vehicle passing at a combined relative speed of 180 km h^{-1} .

Why other options are incorrect:

- **Option A:** 100 km h^{-1} is merely the ground speed of the first bus relative to a stationary observer.
- **Option B:** 20 km h^{-1} is the relative speed if both vehicles were traveling in the same direction: $100 - 80 = 20 \text{ km h}^{-1}$.
- **Option C:** 80 km h^{-1} is the ground speed of the second bus.

Question #81 Key: (A)PHYSICS
02. Force & Motion

Which of the following pairs of projection angles will produce the exact same horizontal range ...

CORE CONCEPT & DERIVATION

For a constant initial launch speed, complementary angles of projection (angles that sum to 90°) yield identical horizontal ranges.

Formula / Rule / Reaction:

$$R(\theta) = \frac{v_0^2 \sin(2\theta)}{g}, \quad \sin(2(90^\circ - \theta)) = \sin(180^\circ - 2\theta) = \sin(2\theta)$$

Solution:

- Because the trigonometric identity $\sin(180^\circ - x) = \sin(x)$ holds universally, replacing θ with $(90^\circ - \theta)$ yields:

$$R(90^\circ - \theta) = \frac{v_0^2 \sin(2(90^\circ - \theta))}{g} = \frac{v_0^2 \sin(180^\circ - 2\theta)}{g} = \frac{v_0^2 \sin(2\theta)}{g} = R(\theta)$$
- Check the pairs for complementary status:

$$75^\circ + 15^\circ = 90^\circ$$
- Because 75° and 15° are complementary, both trajectories span the exact same horizontal range.

Why other options are incorrect:

- Option B:** $10^\circ + 20^\circ = 30^\circ \neq 90^\circ$; their sine products $\sin(20^\circ)$ and $\sin(40^\circ)$ are unequal.
- Option C:** $45^\circ + 60^\circ = 105^\circ \neq 90^\circ$; 45° yields maximum range, while 60° yields 86.6% of maximum.
- Option D:** $0^\circ + 30^\circ = 30^\circ \neq 90^\circ$; a launch at 0° over flat ground yields zero range.

Question #82 Key: (D)PHYSICS
02. Force & Motion

The angle of projection of a projectile for which its maximum vertical height [Formula] and hor...

CORE CONCEPT & DERIVATION

Equating the mathematical expressions for maximum vertical height and horizontal range yields a direct relation between the launch angle θ and the tangent function.

Formula / Rule / Reaction:

$$H = \frac{v_0^2 \sin^2 \theta}{2g}, \quad R = \frac{v_0^2 \sin(2\theta)}{g} = \frac{2v_0^2 \sin \theta \cos \theta}{g}$$

Solution:

- Set the maximum height equal to the horizontal range ($H = R$):

$$\frac{v_0^2 \sin^2 \theta}{2g} = \frac{2v_0^2 \sin \theta \cos \theta}{g}$$
- Cancel common terms v_0^2/g and divide both sides by $\sin \theta$ (for $\theta \neq 0^\circ$):

$$\frac{\sin \theta}{2} = 2 \cos \theta$$
- Rearrange to solve for the tangent of the launch angle:

$$\frac{\sin \theta}{\cos \theta} = \tan \theta = 4$$
- Taking the inverse tangent:

$$\theta = \arctan(4) \approx 75.96^\circ \approx 76^\circ$$

Why other options are incorrect:

- Option A:** At 45° , $R = 4H$; horizontal range is four times the maximum height, not equal to it.
- Option B:** At 90° , $R = 0$ while H reaches its absolute maximum, making them completely unequal.
- Option C:** At 0° , both height and range are zero for a ground-level launch.

Question #83 Key: (C)PHYSICS
02. Force & Motion

The explosion of an explosive projectile into multiple fragments in mid-air is an application o...

CORE CONCEPT & DERIVATION

During an explosion, the explosive forces generated by expanding chemical gases are internal forces within the system; in the absence of net external impulses, total linear momentum is strictly conserved.

Formula / Rule / Reaction:

$$\mathbf{P}_{\text{system}} = \sum m_i \mathbf{v}_i = \text{constant} \implies M \mathbf{v}_{\text{shell}} = \sum m_{\text{fragment}} \mathbf{v}_{\text{fragment}}$$

Solution:

- The chemical detonation occurs over an extremely brief time interval ($\Delta t \rightarrow 0$).
- Because the internal explosive forces are thousands of times larger than external gravity, the external impulse during the blast is negligible.
- Therefore, the vector sum of linear momenta of all flying fragments immediately after detonation equals the momentum of the intact projectile immediately before exploding.
- Mechanical kinetic energy is not conserved because internal chemical potential energy is converted into kinetic energy.

Why other options are incorrect:

- Option A:** Mechanical kinetic energy increases dramatically due to the conversion of chemical potential energy into kinetic energy, violating conservation of mechanical energy alone.
- Option B:** Mass-energy interconversion applies to nuclear reactions ($E = mc^2$), whereas ordinary chemical explosions conserve rest mass.
- Option D:** Newton's first law governs rectilinear inertia in non-accelerating frames; it does not govern multi-body fragment interactions.

Question #84 Key: (A)PHYSICS
03. Work & Energy

One imperial mechanical horsepower (hp) is equivalent in the SI system to:

CORE CONCEPT & DERIVATION

Horsepower is an imperial unit of power defined historically by James Watt as the ability to perform 550 foot-pounds of mechanical work per second.

Formula / Rule / Reaction:

$$1 \text{ hp} = 550 \text{ ft} \cdot \text{lbf s}^{-1} = 550 \times (0.3048 \text{ m}) \times (4.44822 \text{ N}) \approx 745.7 \text{ W} \approx 746 \text{ W}$$

Solution:

- Converting foot-pounds per second to SI base units:

$$1 \text{ ft} = 0.3048 \text{ m}, \quad 1 \text{ lbf} \approx 4.44822 \text{ N}$$
- Multiplying the imperial factors gives:

$$1 \text{ hp} = 550 \times 0.3048 \times 4.44822 \text{ J s}^{-1} = 745.699 \text{ W}$$
- In standard engineering and physics curricula, this value is rounded to 746 watts.

Why other options are incorrect:

- Option B:** 476 watts is an incorrect permutation of the digits 7, 4, and 6.
- Option C:** 647 watts is another numerical anagram of the true conversion value.
- Option D:** 467 watts is an inverted distractor.

Question #85 Key: (C)PHYSICS
10. Electromagnetism

The scalar dot product of a constant force vector [Formula] and the instantaneous velocity vect...

CORE CONCEPT & DERIVATION

Instantaneous mechanical power is the time rate at which work is performed by an applied force on a moving body.

Formula / Rule / Reaction:

$$P = \frac{dW}{dt} = \frac{\mathbf{F} \cdot d\mathbf{r}}{dt} = \mathbf{F} \cdot \left(\frac{d\mathbf{r}}{dt}\right) = \mathbf{F} \cdot \mathbf{v} = Fv \cos \theta$$

Solution:

- Work done by an applied force over an infinitesimal displacement $d\mathbf{r}$ is given by $dW = \mathbf{F} \cdot d\mathbf{r}$.
- Dividing both sides by the elapsed time interval dt gives the rate of work performance.
- Because $d\mathbf{r}/dt$ is the instantaneous velocity $\mathbf{v}$, power is expressed as $P = \mathbf{F} \cdot \mathbf{v}$.

Why other options are incorrect:

- **Option A:** Kinetic energy is the energy possessed by a body due to its motion ($E_k = \frac{1}{2}mv^2$), measured in joules, not watts.
- **Option B:** Potential energy is stored energy associated with configuration within a conservative field (such as mgh), measured in joules.
- **Option D:** Work done is the dot product of force and finite displacement ($W = \mathbf{F} \cdot \mathbf{d}$), representing total energy transferred, whereas $\mathbf{F} \cdot \mathbf{v}$ is the instantaneous rate of energy transfer.

Question #86 Key: (B)PHYSICS
03. Work & Energy

One kilowatt-hour ([Formula]) of electrical energy is equivalent in SI joules to:

CORE CONCEPT & DERIVATION

The kilowatt-hour is a commercial unit of electrical energy representing the work performed by a power dissipation of one kilowatt over an uninterrupted duration of one hour.

Formula / Rule / Reaction:

$$\text{Energy (J)} = \text{Power (W)} \times \text{Time (s)}$$

Solution:

- Convert the power rating to base watts:
 $1 \text{ kW} = 1000 \text{ W} = 10^3 \text{ J s}^{-1}$
- Convert the duration of one hour to base seconds:
 $1 \text{ hour} = 60 \text{ minutes} \times 60 \text{ seconds} = 3600 \text{ s}$
- Calculate total energy by multiplication:
 $1 \text{ kWh} = (1000 \text{ J s}^{-1}) \times (3600 \text{ s}) = 3,600,000 \text{ J} = 3.6 \times 10^6 \text{ J} = 3.6 \text{ MJ}$

Why other options are incorrect:

- **Option A:** 36 MJ is ten times too large (representing 10 kWh).
- **Option C:** 36 kJ represents $3.6 \times 10^4 \text{ J}$, which is two orders of magnitude too small.
- **Option D:** 3.6 kJ represents 3600 J, which corresponds to one watt-hour ($1 \text{ W} \cdot \text{h}$), not one kilowatt-hour.

Question #87 Key: (A)PHYSICS
03. Work & Energy

The amount of work done in moving a body from a given point in a gravitational field to a posit...

CORE CONCEPT & DERIVATION

Absolute gravitational potential energy is defined as the work done by an external agent against the gravitational force in bringing a unit or finite mass from infinity (zero reference potential) to a specific radial position without changing its kinetic energy.

Formula / Rule / Reaction:

$$U = -\frac{GMm}{r} \quad \text{where } U(\infty) = 0$$

Solution:

- Because gravitational forces are attractive, an object's potential energy increases as it moves farther from the attracting mass.
- Choosing infinity as the reference point of zero potential energy makes potential energy negative at all finite distances r .
- The work required to move a mass m from distance r to infinity without acceleration equals:

$$W = \int_r^\infty \frac{GMm}{x^2} dx = \left[-\frac{GMm}{x}\right]_r^\infty = 0 - \left(-\frac{GMm}{r}\right) = +\frac{GMm}{r}$$

- This work quantity defines absolute gravitational potential energy.

Why other options are incorrect:

- **Option B:** Kinetic energy is the energy associated with an object's macroscopic motion ($\frac{1}{2}mv^2$).
- **Option C:** Elastic potential energy is mechanical energy stored in a deformed elastic material (such as a compressed or stretched spring, $\frac{1}{2}kx^2$).
- **Option D:** Electric potential is the work done per unit charge in an electrostatic field, not a mass in a gravitational field.

Question #88 Key: (B)PHYSICS
03. Work & Energy

If the translational speed of a body of mass [Formula] is doubled, its resulting kinetic energy...

CORE CONCEPT & DERIVATION

Kinetic energy is quadratic with respect to velocity, so doubling speed quadruples total kinetic energy.

Formula / Rule / Reaction:

$$E_k = \frac{1}{2}mv^2$$

Solution:

- Let the initial speed of the body be v , giving an initial kinetic energy of $E_{k1} = \frac{1}{2}mv^2$.
- When speed is doubled, the new speed becomes $v' = 2v$.
- Substitute v' into the kinetic energy equation:
 $E_{k2} = \frac{1}{2}m(2v)^2 = \frac{1}{2}m(4v^2) = 2mv^2$
- This new value $2mv^2$ is four times the original value ($4 \times \frac{1}{2}mv^2$).

Why other options are incorrect:

- **Option A:** mv^2 corresponds to only twice the original kinetic energy, which would result from increasing speed by a factor of $\sqrt{2}$.
- **Option C:** $\frac{1}{2}mv^2$ is the original, un-doubled kinetic energy.
- **Option D:** $4mv^2$ represents $8 \times (\frac{1}{2}mv^2)$, an eight-fold increase, which is mathematically incorrect for doubling velocity.

Question #89 Key: (D)PHYSICS
03. Work & Energy

An industrial electric motor is rated at [Formula]. Assuming 100% operational efficiency, its...

CORE CONCEPT & DERIVATIONMechanical power rated in horsepower can be converted directly to watts using the standard conversion factor $1 \text{ hp} = 746 \text{ W}$.**Formula / Rule / Reaction:**

$$P(\text{W}) = P(\text{hp}) \times 746 \text{ W hp}^{-1}$$

Solution:

- Given a motor power rating of $P = 2 \text{ hp}$:
- Apply the standard equivalence relation:

$$P = 2 \text{ hp} \times 746 \text{ W hp}^{-1} = 1492 \text{ W}$$
- Thus, the motor delivers 1492 watts (or 1.492 kW) of mechanical power.

Why other options are incorrect:

- Option A:** 1500 W is an imprecise approximation assuming $1 \text{ hp} = 750 \text{ W}$.
- Option B:** 742 W is close to the single horsepower rating (746 W) and omits the factor of 2.
- Option C:** 148 W is missing an order of magnitude.

Question #90 Key: (C)PHYSICS
04. Rotational & Circular Motion

One radian of angular displacement is equivalent in sexagesimal degrees to approximately:

CORE CONCEPT & DERIVATION

A radian is the plane angle subtended at the center of a circle by an arc whose length is equal to the radius of that circle.

Formula / Rule / Reaction:

$$2\pi \text{ rad} = 360^\circ \implies 1 \text{ rad} = \frac{180^\circ}{\pi}$$

Solution:

- Using the value $\pi \approx 3.14159$:

$$1 \text{ rad} = \frac{180^\circ}{3.14159265...} \approx 57.2958^\circ$$
- Rounding to one decimal place yields 57.3° .

Why other options are incorrect:

- Option A:** 53.7° is an inverted permutation of the digits 5, 7, and 3.
- Option B:** 73.5° is an incorrect permutation.
- Option D:** 37.5° is numerically incorrect.

Question #91 Key: (C)PHYSICS
04. Rotational & Circular Motion

The minimum orbital velocity required to place and maintain an artificial satellite in a stable...

CORE CONCEPT & DERIVATION

Critical velocity (also known as orbital velocity) is the exact tangential speed needed for the centripetal acceleration of a satellite to match the local acceleration due to gravity.

Formula / Rule / Reaction:

$$F_c = F_g \implies \frac{mv_c^2}{R} = \frac{GMm}{R^2} \implies v_c = \sqrt{\frac{GM}{R}} = \sqrt{gR} \approx 7.9 \text{ km s}^{-1}$$

Solution:

- For a satellite orbiting near Earth's surface (radius $R \approx 6.4 \times 10^6 \text{ m}$), gravity provides the necessary centripetal force to keep it in circular motion.
- Solving for tangential speed gives:

$$v_c = \sqrt{(9.8 \text{ m s}^{-2})(6.4 \times 10^6 \text{ m})} \approx 7.92 \times 10^3 \text{ m s}^{-1} \approx 7.9 \text{ km s}^{-1}$$
- If its speed drops below this critical threshold, the satellite spirals down into the denser atmosphere; if it exceeds escape velocity, it leaves orbit completely.

Why other options are incorrect:

- Option A:** Terminal velocity is the constant maximum speed reached by a falling object when aerodynamic drag balances downward weight.
- Option B:** Escape velocity is the minimum launch speed required for an unpowered projectile to overcome Earth's gravitational field completely ($v_{\text{esc}} = \sqrt{2}v_c \approx 11.2 \text{ km s}^{-1}$).
- Option D:** Average velocity is the ratio of total displacement to total elapsed time.

Question #92 Key: (D)PHYSICS
04. Rotational & Circular Motion

A flywheel completes [Formula] in an elapsed time of [Formula]. Its average angular velocity is...

CORE CONCEPT & DERIVATIONAverage angular velocity (ω) is defined as the total angular displacement ($\Delta\theta$) divided by the total time interval (Δt).**Formula / Rule / Reaction:**

$$\omega_{\text{avg}} = \frac{\Delta\theta}{\Delta t}, \quad 1 \text{ rev} = 2\pi \text{ rad}$$

Solution:

- Convert the angular displacement of 12 revolutions into radians:

$$\Delta\theta = 12 \text{ rev} \times 2\pi \text{ rad rev}^{-1} = 24\pi \text{ rad}$$
- Divide total displacement by the time interval $\Delta t = 4 \text{ s}$:

$$\omega_{\text{avg}} = \frac{24\pi \text{ rad}}{4 \text{ s}} = 6\pi \text{ rad s}^{-1}$$
- Substitute $\pi \approx 3.14159$:

$$\omega_{\text{avg}} = 6 \times 3.14159 \approx 18.85 \text{ rad s}^{-1} \approx 18.8 \text{ rad s}^{-1}$$

Why other options are incorrect:

- Option A:** 24.6 rad s^{-1} is an arithmetic miscalculation.
- Option B:** 16.8 rad s^{-1} results from using an incorrect conversion factor.
- Option C:** 10.4 rad s^{-1} is far below the correct rotational value.

Question #93 Key: (A)PHYSICS
04. Rotational & Circular Motion

When a particle executes uniform circular motion in a plane, the direction of its centripetal a...

CORE CONCEPT & DERIVATION

In uniform circular motion, while the orbital speed remains constant, the direction of the velocity vector changes continuously, producing an acceleration directed radially toward the center of rotation.

Formula / Rule / Reaction:

$$\mathbf{a}_c = -\frac{v^2}{r}\hat{\mathbf{r}} = -\omega^2 r\hat{\mathbf{r}}$$

Solution:

- The instantaneous velocity vector $\mathbf{v}$ is always tangent to the circular trajectory at every point.
- Calculating the derivative $d\mathbf{v}/dt$ shows that the change in velocity $\Delta\mathbf{v}$ over an infinitesimal arc points perpendicular to the velocity vector, directed inward along the radius.
- Consequently, centripetal acceleration points toward the center of curvature at all times.

Why other options are incorrect:

- **Option B:** A vector directed along the forward tangent represents tangential acceleration ($a_t = dv/dt$), which occurs only when speed changes.
- **Option C:** A vector directed opposite to forward velocity represents negative tangential deceleration.
- **Option D:** Radially outward direction corresponds to the apparent centrifugal inertial reaction observed in a rotating non-inertial reference frame, not real centripetal acceleration.

Question #94 Key: (A)PHYSICS
05. Waves

In a ripple tank experiment using a point light source above water waves, the crest of a surfac...

CORE CONCEPT & DERIVATION

Because the water surface bulges upward at a wave crest, it is thicker in the middle than at the edges, acting like a converging (convex) cylindrical lens that focuses light rays into bright bands on a screen below.

Formula / Rule / Reaction:

Crest: Thicker in center $\Rightarrow$ Converging (Convex) Lens Action $\rightarrow$ Bright Lines

Trough: Thinner in center $\Rightarrow$ Diverging (Concave) Lens Action $\rightarrow$ Dark Bands

Solution:

- In a ripple tank, light illuminates water waves from above, and patterns are cast on a viewing screen below.
- A wave crest forms a convex meniscus: light rays refracting through this curved water layer converge toward the central axis.
- This convergence produces focused bright fringes on the screen beneath each crest, demonstrating convex lens behavior.

Why other options are incorrect:

- **Option B:** The trough of a wave is thinner in the middle and curved inward, acting like a concave (diverging) lens that spreads light rays to produce dark bands.
- **Option C:** A convex mirror reflects light rather than refracting transmitted light through water.
- **Option D:** A plane mirror reflects light uniformly without converging or diverging rays to create focal bands.

Question #95 Key: (B)PHYSICS
05. Waves

The speed of sound in air is independent of which of the following physical variables at consta...

CORE CONCEPT & DERIVATION

According to Laplace's formula for acoustic propagation in an ideal gas, an increase in hydrostatic pressure produces a proportional increase in gas density at constant temperature, leaving sound speed unchanged.

Formula / Rule / Reaction:

$$v = \sqrt{\frac{\gamma P}{\rho}} \quad \text{and} \quad \frac{P}{\rho} = \frac{RT}{M} \Rightarrow v = \sqrt{\frac{\gamma RT}{M}}$$

Solution:

- Boyle's law states that at constant temperature, pressure is directly proportional to density ($P/\rho = \text{constant}$).
- If atmospheric pressure is doubled, the air compresses such that density doubles simultaneously.
- Because the ratio P/ρ remains constant, ambient pressure changes have no net effect on the speed of sound.

Why other options are incorrect:

- **Option A:** Moisture decreases the effective molar mass of humid air relative to dry air, which slightly increases sound speed.
- **Option C:** Sound speed varies directly with the square root of absolute temperature ($v \propto \sqrt{T}$).
- **Option D:** At a given pressure, changing gas density (by substituting a different gas like helium) alters the speed of sound.

Question #96 Key: (C)ENGLISH
06. Punctuation, Capitalization & Reading Comprehension

Choose the grammatically and punctually correct sentence:

CORE CONCEPT & DERIVATION

Two independent clauses that are closely related in thought but lack a coordinating conjunction must be joined by a semicolon; when two subsequent independent clauses are joined by a coordinating conjunction ('and'), they must be separated by a comma.

Formula / Rule / Reaction:

[Independent Clause 1]; [Independent Clause 2], and [Independent Clause 3].

Solution:

- The sentence contains three distinct independent clauses: (1) 'He had no worries', (2) 'his pension was adequate', and (3) 'there was a little money saved up besides'.
- Joining clause 1 and clause 2 without a coordinating conjunction requires a semicolon to avoid a run-on or comma splice.
- Clause 2 and clause 3 are joined by the coordinating conjunction 'and', requiring a comma before 'and'.
- Therefore, Option C provides the correct punctuation.

Why other options are incorrect:

- **Option A:** This is a run-on (fused) sentence that lacks punctuation between the first two independent clauses.
- **Option B:** Using a comma alone to separate the first two independent clauses creates a comma splice error.
- **Option D:** The colon is used inappropriately here because the second clause does not serve as an explanatory list or formal apposition, and it omits the comma before the coordinating conjunction 'and'.

Question #97 **Key: (B)**ENGLISH
05. Active-Passive Voice, Reported Speech & Syntax

Identify the error and choose the correctly structured sentence:

CORE CONCEPT & DERIVATION

The subjective relative pronoun 'who' must be used when the pronoun serves as the subject of the subordinate clause predicate ('is the best portrait painter'), even when separated by a parenthetical phrase ('they say').

Formula / Rule / Reaction:

Relative Pronoun as Subject: who [they say] is ... (Test: **He** is the painter, not **him**)

Solution:

- Temporarily remove the parenthetical attribution 'they say': the clause becomes 'who is the best portrait painter in the town'.
- Because the pronoun is the grammatical subject of the verb 'is', the subjective form 'who' is required, ruling out the objective form 'whom'.
- A comma is placed before the non-restrictive relative clause adding descriptive information about a proper noun ('Mr. Hashim').
- The superlative adjective 'best' requires the definite article 'the best'.

Why other options are incorrect:

- Option A:** Uses the objective pronoun 'whom' as the subject of the clause 'is the best portrait painter'.
- Option C:** Contains a misplaced apostrophe ('Theres') and uses the relative pronoun 'which', which refers to non-human entities rather than people.
- Option D:** Omits the definite article 'the' before the superlative adjective 'best' and lacks proper parenthetical punctuation.

Question #98 **Key: (C)**ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Complete the sentence with correct subject-verb agreement: 'A full description of car accidents...

CORE CONCEPT & DERIVATION

The verb in a sentence must agree in grammatical number with its true subject noun phrase, rather than with an intervening prepositional modifier.

Formula / Rule / Reaction:

A full description [singular subject] ... **was** [singular verb]

Solution:

- Identify the head noun of the subject noun phrase: 'A full description'.
- The phrase 'of car accidents' is an intervening prepositional phrase acting as an adjectival modifier.
- Even though 'accidents' is plural, the head noun 'description' is singular and requires the singular auxiliary verb 'was'.

Why other options are incorrect:

- Option A:** 'are' is a plural present verb that disagrees with the singular subject 'description'.
- Option B:** 'have been' is a plural verb phrase that disagrees with the singular head noun.
- Option D:** 'were' is a plural past tense verb that mistakenly agrees with the object of the preposition ('accidents') instead of the true subject.

Question #99 **Key: (A)**ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Select the grammatically correct verb form to complete the sentence: 'Ahmad _____ me for a long...

CORE CONCEPT & DERIVATION

An action or state of knowing that began in the past and continues up to the present moment, qualified by the time preposition 'for', requires the present perfect tense with third-person singular agreement.

Formula / Rule / Reaction:

Subject (3rd Person Singular) + **has** + **V₃** (Past Participle) + for / since [time expression]

Solution:

- The adverbial time expression 'for a long time' indicates an ongoing duration of an acquaintance originating in the past and continuing into the present.
- The stative verb 'know' cannot take progressive aspects ('is knowing').
- The third-person singular subject 'Ahmad' requires the singular auxiliary 'has' combined with the past participle 'known' (has known).

Why other options are incorrect:

- Option B:** 'have known' uses a plural auxiliary verb that disagrees with the singular subject 'Ahmad'.
- Option C:** 'knows' (simple present) denotes a habitual action or general state, but does not indicate duration spanning from the past to the present with 'for'.
- Option D:** 'knew' (simple past) implies a terminated past acquaintance that no longer persists today.

Question #100 **Key: (C)**ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

In the sentence, 'He is appreciated for being ambidextrous', the underlined vocabulary word me...

CORE CONCEPT & DERIVATION

Etymologically derived from Latin 'ambi-' (both) and 'dexter' (right-handed or skillful), 'ambidextrous' describes the ability to use both hands with equal skill.

Formula / Rule / Reaction:

Ambi (both) + Dexter (right-handed / skillful) = Equally adept with both hands

Solution:

- A person who is ambidextrous does not have a single dominant hand, showing equal dexterity with both hands.
- In descriptive English, it specifically denotes being able to write or perform manual tasks equally well with either hand.

Why other options are incorrect:

- Option A:** Physical agility or quickness corresponds to being agile, nimble, or lithe.
- Option B:** Displaying wisdom and intellect corresponds to being sagacious, prudent, or erudite.
- Option D:** Remaining strictly focused and concise corresponds to being succinct, pithy, or concise.

Question #101 Key: (B)ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

In the sentence, 'He visited the ghettos for the first time', the underlined vocabulary word means...

CORE CONCEPT & DERIVATION

A ghetto is historically and sociologically defined as a densely populated, economically depressed, and marginalized urban slum area occupied predominantly by minority groups experiencing social or legal pressures.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- The term originated in 16th-century Venice to describe segregated quarters designated for Jewish residents.
- In contemporary vocabulary, it denotes economically deprived, impoverished, and socially isolated inner-city areas characterized by low-income housing and limited infrastructure.

Why other options are incorrect:

- **Option A:** Affluent residential areas describe wealthy suburbs or enclaves, the antonym of a ghetto.
- **Option C:** Pristine commercial areas denote clean business districts, contrasting with the poverty implied by ghetto.
- **Option D:** Modern technological parks represent developed industrial developments.

Question #102 Key: (D)ENGLISH
03. Parts of Speech, Prepositions & Modifiers

Select the appropriate collective noun to complete the sentence: 'My friend has a fine _____ of...'.

CORE CONCEPT & DERIVATION

In standard English grammar, specific items when systematically accumulated, preserved, or classified take specific conventional collective nouns (a collection of stamps/coins).

Formula / Rule / Reaction:

Standard Collocation: A collection of stamps / coins / antiques

Solution:

- The systematic assembly of philatelic items (postage stamps) represents a 'collection'.
- Therefore, 'a fine collection of old stamps' is the established idiomatic and grammatical noun phrase.

Why other options are incorrect:

- **Option A:** 'Group' is an unspecific term typically used for people, organisms, or arbitrary clusters.
- **Option B:** 'Bridge' denotes a card game, an engineering structure spanning an obstacle, or an anatomical connection.
- **Option C:** 'Band' is a collective noun reserved for musicians, nomads, or robbers.

Question #103 Key: (D)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Choose the grammatically correct sentence conforming to subject-verb agreement:

CORE CONCEPT & DERIVATION

The indefinite distributive pronoun 'every one' is grammatically singular and requires a singular verb, regardless of any intervening plural prepositional phrase ('of the prisons').

Formula / Rule / Reaction:

Every one [singular subject] + of the [plural noun] + **is** [singular verb]

Solution:

- Analyze the subject structure: 'Every one' focuses distributively on individual items taken one at a time.
- The intervening phrase 'of the prisons' modifies 'every one' without altering its singular grammatical number.
- Therefore, the singular linking verb 'is' is required.

Why other options are incorrect:

- **Option A:** 'are' is a plural verb that erroneously agrees with the plural noun 'prisons' rather than the singular subject 'every one'.
- **Option B:** 'had full' is an ungrammatical verb phrase construction lacking a participle or predicate adjective linkage.
- **Option C:** 'have full' incorrectly uses a plural verb without a valid predicate complement.

Question #104 Key: (A)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Select the grammatically correct verb form to complete the sentence: 'The headmaster _____ to S...'.

CORE CONCEPT & DERIVATION

The verb 'want' is a stative verb of desire that does not take progressive (-ing) aspects under standard conditions, and must agree with a third-person singular subject in the simple present tense.

Formula / Rule / Reaction:

The headmaster [3rd person singular] + **wants** [simple present stative verb]

Solution:

- Stative verbs express mental states, emotions, or conditions rather than physical actions; they are used in simple tenses rather than continuous tenses.
- The subject 'The headmaster' is singular, so the base verb 'want' takes the singular inflectional suffix '-s' in the simple present tense: 'wants'.

Why other options are incorrect:

- **Option B:** 'is wanting' incorrectly places the stative verb 'want' into the present continuous tense.
- **Option C:** 'was wanting' uses an unidiomatic past continuous form for a stative verb.
- **Option D:** 'want' is the plural base form, which lacks singular agreement with 'The headmaster'.

Question #105 Key: (B)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Complete the sentence with correct subject-verb agreement: 'Knowledge and wisdom ----- no time ...'

CORE CONCEPT & DERIVATION

When two distinct abstract nouns are joined by the coordinating conjunction 'and' to denote two separate attributes, they form a compound subject that requires a plural verb.

Formula / Rule / Reaction:

Noun₁ + and + Noun₂ ⇒ Plural Compound Subject → have

Solution:

- While singular compound pairings exist when two nouns describe a single unified idea (such as 'bread and butter' or 'slow and steady'), 'knowledge' and 'wisdom' denote distinct intellectual qualities.
- Because they are treated as two distinct entities coordinated by 'and', the compound subject is plural.
- Therefore, it takes the plural present tense verb 'have'.

Why other options are incorrect:

- Option A:** 'has' is a singular verb that disagrees with the compound plural subject.
- Option C:** 'had' indicates past tense, which alters the general present-tense statement of the proposition.
- Option D:** 'is' is singular and does not fit the transitive structure requiring a verb of possession.

Question #106 Key: (A)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Complete the sentence with correct subject-verb agreement: 'Each of the boys ----- to ride.'

CORE CONCEPT & DERIVATION

The indefinite distributive pronoun 'each' refers to members of a group individually and is grammatically singular, taking a singular verb regardless of any following plural prepositional phrase.

Formula / Rule / Reaction:

Each [singular subject] + of the boys + loves [singular verb]

Solution:

- The grammatical subject of the sentence is the distributive pronoun 'Each'.
- The prepositional phrase 'of the boys' modifies the subject without changing its singular number.
- In the simple present tense, singular third-person verbs take the '-s' inflection: 'loves'.

Why other options are incorrect:

- Option B:** 'love' is a plural verb that mistakenly agrees with 'boys' instead of 'Each'.
- Option C:** 'are loving' uses a plural auxiliary and incorrectly places a stative emotion verb into the progressive aspect.
- Option D:** 'have loved' uses a plural auxiliary that disagrees with the singular subject 'Each'.

Question #107 Key: (B)ENGLISH
04. Subject-Verb Agreement, Tenses & Conditionals

Choose the sentence that is correctly punctuated and structured:

CORE CONCEPT & DERIVATION

Parenthetical phrases introduced by expressions like 'together with', 'along with', or 'as well as' are set off by commas and do not change the grammatical number of the singular subject.

Formula / Rule / Reaction:

Subject (singular), together with [...], Verb (singular)

Solution:

- The core subject is 'Mr. Shan', which is singular.
- The modifying phrase ', together with his family,' is non-essential and set off by matching commas.
- Because this modifying phrase does not compound the subject (unlike 'and'), the verb remains singular: 'goes'.

Why other options are incorrect:

- Option A:** Lacks the required commas setting off the modifying phrase and contains awkward word order ('together goes').
- Option C:** Uses the plural verb 'go', failing to maintain singular agreement with 'Mr. Shan'.
- Option D:** Uses the plural verb 'go' and has awkward comma placement with 'together'.

Question #108 Key: (C)ENGLISH
06. Punctuation, Capitalization & Reading Comprehension

Identify the error and choose the correctly capitalized and structured sentence:

CORE CONCEPT & DERIVATION

Proper adjectives of nationality must be capitalized, the singular subject must agree with a singular verb, and a superlative adjective modifying a noun requires the definite article 'the'.

Formula / Rule / Reaction:

Proper Adjective (Capitalized) + Singular Subject + Singular Verb + the [Superlative]
Solution:

- 'English' is a proper adjective derived from a proper noun (England) and must be capitalized.
- The subject 'The English man' is third-person singular, requiring the singular verb 'thinks' rather than the plural 'think'.
- The superlative adjective 'best' requires the definite article 'the best'.

Why other options are incorrect:

- Option A:** Fails to capitalize the proper adjective ('english').
- Option B:** Uses the plural verb form 'think', which disagrees with the singular subject 'The English man'.
- Option D:** Uses the plural verb 'think' and omits the definite article 'the' before 'best'.

Question #109 Key: (D)

ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

Select the option containing the correct orthographic spelling:

CORE CONCEPT & DERIVATION

Standard English orthography derives the technical noun 'apparatus' directly from Latin 'apparatus' (tools or equipment), maintaining double 'p' and single 't'.

Formula / Rule / Reaction:

Spelling: A - P - P - A - R - A - T - U - S

Solution:

- The correct spelling is 'Apparatus'.
- It consists of four syllables: ap-pa-ra-tus.

Why other options are incorrect:

- Option A:** 'Appratus' omits the second vowel 'a'.
- Option B:** 'Aprattus' erroneously doubles the 't' while using a single 'p'.
- Option C:** 'Appretis' introduces an incorrect vowel ending.

Question #110 Key: (C)

ENGLISH
01. Vocabulary, Synonyms, Antonyms & Spelling

Select the option containing the correct orthographic spelling:

CORE CONCEPT & DERIVATION

Derived from Latin 'mercenarius' (working for hire, from 'merces' meaning wages), the word is spelled with a 'c' and ends in '-ary'.

Formula / Rule / Reaction:

Spelling: M - E - R - C - E - N - A - R - Y

Solution:

- The correct spelling is 'Mercenary'.
- The root uses 'c' to make the soft /s/ sound, and ends in the adjectival suffix '-ary'.

Why other options are incorrect:

- Option A:** 'Mercenery' incorrectly substitutes the suffix '-ery' for '-ary'.
- Option B:** 'Mersanary' phonetically misspells the root with 's' and an incorrect central vowel 'a'.
- Option D:** 'Mersenary' incorrectly replaces 'c' with 's'.

Question #111 Key: (C)

CHEMISTRY
11. S & P Block Elements

Which of the following metal halide compounds exhibits significant covalent character in its ch...

CORE CONCEPT & DERIVATION

According to Fajan's rules, covalent character is favored by a small cation size, high positive charge, and high charge density, which polarizes the electron cloud of the anion.

Formula / Rule / Reaction:

$$\text{Polarizing Power} \propto \frac{\text{Cationic Charge}}{\text{Cationic Radius}} = \frac{z}{r}$$

Solution:

- Compare the cations of Period 3: Na^+ , Mg^{2+} , and Al^{3+} .
- The Al^{3+} cation has a high +3 charge and a very small ionic radius (approximately 53.5 pm), giving it an exceptionally high charge density.
- This strong polarizing power distorts the large electron cloud of the chloride anion (Cl^-), pulling electron density between the nuclei and creating substantial covalent character.
- As a result, anhydrous AlCl_3 sublimes at 180°C and exists as covalent dimers (Al_2Cl_6) in the vapor phase.

Why other options are incorrect:

- Option A:** NaCl contains the larger Na^+ cation with lower polarizing power, forming an ionic crystal lattice.
- Option B:** MgCl_2 exhibits predominantly ionic character with a high melting point (714°C).
- Option D:** KCl contains the large K^+ cation with low charge density, forming a classic ionic solid.

Question #112 Key: (B)

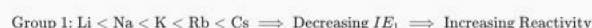
CHEMISTRY
11. S & P Block Elements

Which of the following periodic properties increases progressively down Group 1 (alkali metals)...

CORE CONCEPT & DERIVATION

The chemical reactivity of alkali metals depends on how easily they lose their single valence s^1 electron to form univalent cations (M^+), which becomes progressively easier as atomic radius increases and first ionization energy decreases down the group.

Formula / Rule / Reaction:



Solution:

- Descending Group 1 adds successive principal electron shells, increasing the atomic radius and the shielding effect of inner core electrons.
- The valence electron is held less tightly by the nucleus, leading to a monotonic decrease in first ionization energy from Li to Cs.
- Because less energy is needed to remove the valence electron, chemical reactivity increases down the group.

Why other options are incorrect:

- Option A:** First ionization energy decreases down Group 1 as the outer shell moves farther from the nucleus.
- Option C:** Electron affinity becomes less exothermic (decreases) down the group because the larger radius reduces attraction for an added electron.
- Option D:** Electronegativity decreases down Group 1 (from 1.0 for Li to 0.7 for Cs) due to increased atomic size and screening.

Question #113 Key: (A)

CHEMISTRY
11. S & P Block Elements

The aqueous solubility of Group 2 (alkaline earth metal) sulfate salts behaves in which of the ...

CORE CONCEPT & DERIVATION

Solubility is governed by the thermodynamic balance between lattice enthalpy and hydration enthalpy; for alkaline earth metal sulfates with large divalent anions, hydration enthalpy decreases more rapidly than lattice enthalpy down the group.

Formula / Rule / Reaction:

$$\Delta H_{\text{solution}} = \Delta H_{\text{lattice}} - \Delta H_{\text{hydration}}$$

Solution:

- The sulfate anion (SO_4^{2-}) has a very large ionic radius that dominates the lattice parameter.
- Because the anion is so large, increasing the cation radius down Group 2 ($\text{Be}^{2+} \rightarrow \text{Ba}^{2+}$) causes only a modest percentage increase in internuclear separation, so lattice energy decreases only slightly.
- However, cationic hydration enthalpy is inversely proportional to cation radius and decreases rapidly as the cation size increases.
- Because hydration enthalpy drops faster than lattice enthalpy, $\Delta H_{\text{solution}}$ becomes increasingly endothermic, causing sulfate solubility to decrease from highly soluble BeSO_4 to insoluble BaSO_4 .

Why other options are incorrect:

- Option B:** Increasing solubility down the group describes Group 2 hydroxides (where small OH^- anions allow lattice energy to drop faster than hydration energy).
- Option C:** Solubility varies by several orders of magnitude, rather than remaining constant.
- Option D:** The decrease in solubility is monotonic from beryllium down to barium.

Question #114 Key: (D)

CHEMISTRY
13. Fundamental Principles of Organic Chemistry

Geometric isomerism (cis-trans isomerism) is typically exhibited by which of the following homo...

CORE CONCEPT & DERIVATION

Geometric isomerism requires restricted rotation about a chemical bond and the presence of two non-identical ligand groups attached to each of the two unsaturated carbon atoms.

Formula / Rule / Reaction:

$$\text{Condition: } \text{R}_1\text{R}_2\text{C} = \text{CR}_3\text{R}_4 \quad (\text{where } \text{R}_1 \neq \text{R}_2 \text{ and } \text{R}_3 \neq \text{R}_4)$$

Solution:

- In alkenes, sideways overlap of unhybridized $2p$ atomic orbitals forms a rigid π -bond across the $\text{C} = \text{C}$ double bond.
- Free rotation about this double bond is prevented at ambient temperatures because rotation would require breaking the π -bond (requiring approximately 260 kJ mol^{-1}).
- When each sp^2 carbon carries two different substituents, two diastereomeric configurations arise: the cis isomer (identical groups on the same face) and the trans isomer (identical groups on opposite faces).

Why other options are incorrect:

- Option A:** Saturated aliphatic alcohols possess single $\text{C} - \text{C}$ and $\text{C} - \text{O}$ σ -bonds that rotate freely, exhibiting conformational rather than geometric isomerism.
- Option B:** Ethers have unrestricted rotation about their single $\text{C} - \text{O} - \text{C}$ σ -bonds.
- Option C:** Alkynes possess a linear $\text{C} \equiv \text{C}$ triple bond (180° bond angle) with each sp carbon bonded to only one substituent, making spatial cis-trans arrangements geometrically impossible.

Question #115 Key: (C)

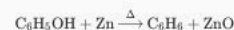
CHEMISTRY
16. Alcohols & Phenols

Benzene can be synthesized directly in the laboratory from phenol by heating it with which of t...

CORE CONCEPT & DERIVATION

Phenol undergoes deoxygenation to benzene when distilled with electropositive zinc dust, which serves as a powerful solid-state reducing agent.

Formula / Rule / Reaction:



Solution:

- Phenol vapor passes over heated zinc dust, where the zinc metal extracts the phenolic oxygen atom due to the high thermodynamic stability of zinc oxide (ZnO).
- The aromatic phenyl ring is reduced back to a benzene hydrocarbon molecule.
- The resulting benzene volatilizes and is condensed as a clear liquid distillate, serving as a classic laboratory preparation method.

Why other options are incorrect:

- Option A:** Catalytic hydrogenation of phenol with H_2 over a nickel catalyst at elevated temperature reduces the aromatic ring to cyclohexanol, rather than yielding benzene.
- Option B:** Phenol reacts with aqueous alkali (NaOH) via an acid-base neutralization to form water-soluble sodium phenoxide ($\text{C}_6\text{H}_5\text{O}^- \text{Na}^+$), without reducing the ring.
- Option D:** Concentrated mineral acids (such as H_2SO_4 or HNO_3) trigger electrophilic aromatic substitution on phenol (sulfonation or nitration), rather than reduction.

Question #116 Key: (C)

CHEMISTRY
16. Alcohols & Phenols

The Lucas test utilizes a solution of anhydrous zinc chloride in concentrated hydrochloric acid...

CORE CONCEPT & DERIVATION

The Lucas test distinguishes primary, secondary, and tertiary monohydric alcohols based on differences in their rates of nucleophilic substitution ($\text{S}_{\text{N}}1$) to form insoluble alkyl chlorides.

Formula / Rule / Reaction:



Solution:

- Lucas reagent consists of equimolar anhydrous ZnCl_2 (a Lewis acid catalyst) dissolved in concentrated HCl .
- Tertiary alcohols form stable carbocations immediately and yield insoluble alkyl chloride turbidity within seconds at room temperature.
- Secondary alcohols react through a slower $\text{S}_{\text{N}}1$ pathway, producing oily turbidity within 5 to 10 minutes.
- Primary alcohols do not form stable carbocations and show no cloudiness at room temperature, requiring prolonged heating to react.

Why other options are incorrect:

- Option A:** Alkyl halides are the insoluble products formed during the test, not the organic reactants being categorized.
- Option B:** Alkenes are identified via bromine water discoloration or Baeyer's test (alkaline KMnO_4).
- Option D:** Carboxylic acids are identified by effervescence of CO_2 with sodium bicarbonate (NaHCO_3).

Question #117 Key: (B)CHEMISTRY
16. Alcohols & Phenols

Under standard ambient conditions, pure phenol exhibits which of the following sets of physical...

CORE CONCEPT & DERIVATION

Pure phenol (carbolic acid) is an aromatic hydroxy compound whose intermolecular hydrogen bonding gives it a well-defined crystalline lattice that readily absorbs atmospheric moisture.

Formula / Rule / Reaction:

Phenol: C_6H_5OH (Melting Point $\approx 41^\circ C$, Boiling Point $\approx 182^\circ C$)

Solution:

- In its pure state, phenol forms needle-shaped, colorless to white crystalline solids with a distinctive medicinal disinfectant odor.
- It is deliquescent, meaning it absorbs moisture from ambient air and liquefies into a pinkish liquid upon standing.
- Its regular crystal lattice is stabilized by intermolecular hydrogen bonds between adjacent phenolic hydroxyl groups.

Why other options are incorrect:

- Option A:** Phenol forms an ordered crystalline lattice with a melting point of $41^\circ C$, rather than an amorphous (non-crystalline) solid.
- Option C:** Phenol is crystalline, not amorphous.
- Option D:** Pure dry phenol is a solid at room temperature ($25^\circ C$), not an oily non-hygroscopic liquid.

Question #118 Key: (A)CHEMISTRY
17. Aldehydes & Ketones

The Cannizzaro reaction is a base-catalyzed redox disproportionation characteristic of which of...

CORE CONCEPT & DERIVATION

The Cannizzaro reaction occurs exclusively in aldehydes that lack α -hydrogen atoms, preventing base-catalyzed enolate formation and aldol condensation.

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

- Formaldehyde ($HCHO$) has no carbon atom attached to the carbonyl group, and therefore possesses zero α -hydrogens.
- When treated with concentrated alkali (such as 50% $NaOH$), hydroxide attacks the carbonyl carbon to form a tetrahedral dianion intermediate.
- This intermediate transfers a hydride ion ($:H^-$) to a second formaldehyde molecule, simultaneously reducing it to methanol and oxidizing the first molecule to sodium formate.

Why other options are incorrect:

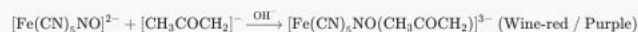
- Option B:** Acetaldehyde (CH_3CHO) possesses three acidic α -hydrogens and readily undergoes base-catalyzed aldol condensation instead.
- Option C:** Acetone (CH_3COCH_3) is a ketone with six α -hydrogens that undergoes aldol self-condensation.
- Option D:** Butanone is a ketone with five α -hydrogens that does not undergo the Cannizzaro reaction.

Question #119 Key: (C)CHEMISTRY
17. Aldehydes & Ketones

Which of the following qualitative analytical tests is used to detect the presence of a ketone ...

CORE CONCEPT & DERIVATION

Ketones react with alkaline sodium nitroprusside solution to form a distinctive wine-red or purple coordination complex, providing a diagnostic analytical test for ketones.

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

- In an alkaline medium, sodium hydroxide removes an α -hydrogen from the ketone, generating a resonance-stabilized carbanion (enolate ion).
- This carbanion attacks the nitrosyl ligand of the nitroprusside complex ion $[Fe(CN)_5NO]^{2-}$.
- The resulting coordination complex produces a deep wine-red or violet coloration, confirming the presence of a ketone.

Why other options are incorrect:

- Option A:** Benedict's solution contains cupric ions complexed with citrate; it oxidizes aliphatic aldehydes to give a red Cu_2O precipitate, but does not react with simple ketones.
- Option B:** Fehling's solution uses tartrate-stabilized Cu^{2+} to selectively detect aldehydes, giving no reaction with ketones.
- Option D:** Tollens' reagent contains ammoniacal silver nitrate $[Ag(NH_3)_2]^+$, which is reduced to elemental silver by aldehydes, but does not react with ketones.

Question #120 Key: (C)CHEMISTRY
18. Carboxylic Acids

Low molecular weight aliphatic carboxylic acids are completely miscible with water primarily be...

CORE CONCEPT & DERIVATION

The high aqueous solubility of carboxylic acids arises from their ability to form multiple intermolecular hydrogen bonds with polar water molecules through both their carbonyl oxygen and hydroxyl groups.

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

- The carboxyl group ($-COOH$) contains a polarized carbonyl bond ($C^{\delta+} = O^{\delta-}$) and a polarized hydroxyl bond ($O^{\delta-} - H^{\delta+}$).
- In water, the cyclic carboxylic acid dimers dissociate, and individual acid molecules form hydrogen bonds with surrounding water molecules.
- This favorable hydration energy readily overcomes the self-association energy of the acid, making lower carboxylic acids (such as formic, acetic, and propionic acids) completely miscible with water.

Why other options are incorrect:

- Option A:** Chemical reactivity governs the rates of covalent bond transformations, not thermodynamic physical solubility.
- Option B:** Melting point reflects crystal lattice stability, not intermolecular interactions with solvent molecules.
- Option D:** Liquid density has no direct thermodynamic connection to solute-solvent miscibility.

Question #121 Key: (A)

CHEMISTRY
04. Gases

Which of the following mathematical relationships represents the equation of state for an ideal...

CORE CONCEPT & DERIVATION

The ideal gas equation unites Boyle's, Charles's, and Avogadro's laws into a single equation of state relating pressure, volume, temperature, and amount of substance.

Formula / Rule / Reaction:

$$V \propto \frac{1}{P} \text{ (Boyle), } V \propto T \text{ (Charles), } V \propto n \text{ (Avogadro)} \implies PV = nRT$$

Solution:

- Combining these empirical proportionality relations shows that gas volume is directly proportional to moles n and absolute temperature T , and inversely proportional to pressure P .

- Introducing the universal gas constant R yields:

$$V = R \left(\frac{nT}{P} \right) \implies PV = nRT$$

- In this relation, P is absolute pressure, V is volume, n is moles, and T is thermodynamic temperature in Kelvin.

Why other options are incorrect:

- Option B:** $PT = nRV$ incorrectly places temperature on the left side alongside pressure.
- Option C:** $P = nRT$ omits the volume variable, making the expression dimensionally invalid.
- Option D:** $T = nPV/R$ incorrectly places moles n in the numerator rather than the denominator (correct: $T = PV/nR$).

Question #122 Key: (D)

CHEMISTRY
04. Gases

To prevent the volume of an ideal gas from expanding when its mass (moles) is increased, how sh...

CORE CONCEPT & DERIVATION

According to the ideal gas law, volume is directly proportional to moles and absolute temperature, and inversely proportional to hydrostatic pressure.

Formula / Rule / Reaction:

$$V = \frac{nRT}{P} = \text{constant} \implies \Delta V = 0$$

Solution:

- If the mass and molar amount of the gas (n) are increased, the product nRT/P will naturally increase unless offset by changes in T or P .
- To counteract this expansion and maintain constant volume ($V = \text{constant}$):
- Lowering the absolute temperature T decreases the average molecular kinetic energy, reducing expansion tendencies.
- Increasing the external pressure P compresses the gas particles into a smaller volume.
- Therefore, lowering the temperature and increasing the pressure prevents the volume from expanding when mass is added.

Why other options are incorrect:

- Option A:** Increasing temperature and lowering pressure would both promote expansion, causing the volume to increase dramatically.
- Option B:** Lowering pressure promotes expansion, counteracting the compressive effect of lower temperature.
- Option C:** Increasing temperature promotes expansion, counteracting the compressive effect of increased pressure.

Question #123 Key: (D)

CHEMISTRY
04. Gases

Which thermodynamic variable from the ideal gas equation is held strictly constant when applyin...

CORE CONCEPT & DERIVATION

The individual classical gas laws describe how two thermodynamic properties change relative to each other in a closed system containing a fixed amount of gas.

Formula / Rule / Reaction:

$$\text{Boyle's Law: } P_1V_1 = P_2V_2 \quad (n, T = \text{constant})$$

$$\text{Charles's Law: } \frac{V_1}{T_1} = \frac{V_2}{T_2} \quad (n, P = \text{constant})$$

$$\text{Gay-Lussac's Law: } \frac{P_1}{T_1} = \frac{P_2}{T_2} \quad (n, V = \text{constant})$$

Solution:

- Each classical gas law isolates the relationship between two specific variables while holding others constant.
- However, all three laws require that no gas enters or leaves the system, meaning the mass and number of moles (n) must remain strictly constant.
- Only Avogadro's law explicitly varies the number of moles.

Why other options are incorrect:

- Option A:** Volume varies in both Boyle's law and Charles's law; it is held constant only in Gay-Lussac's isochoric law.
- Option B:** Temperature varies in Charles's law and Gay-Lussac's law; it is held constant only in Boyle's isothermal law.
- Option C:** Pressure varies in Boyle's law and Gay-Lussac's law; it is held constant only in Charles's isobaric law.

Question #124 Key: (A)

CHEMISTRY
05. Liquids

Which of the following volatile organic and inorganic liquids displays the highest rate of evap...

CORE CONCEPT & DERIVATION

The rate of liquid evaporation is inversely related to the strength of its intermolecular attractive forces; liquids with weaker forces have higher vapor pressures and evaporate more rapidly.

Formula / Rule / Reaction:

$$\text{Rate of Evaporation} \propto \text{Vapor Pressure} \propto \frac{1}{\text{Strength of Intermolecular Forces}}$$

Solution:

- Water, ethanol, and ethylene glycol all form strong intermolecular hydrogen bonds due to their polar $-\text{OH}$ groups (ethylene glycol forms an extensive two-site network, water forms a tetrahedral network, and ethanol forms single-donor chains).
- Acetone (CH_3COCH_3) is a dipolar aprotic liquid held together only by moderate dipole-dipole attractions and London dispersion forces, lacking $\text{O}-\text{H}$ hydrogen bond donors.
- Because its molecules require less energy to escape the liquid surface, acetone exhibits the highest vapor pressure and evaporates most rapidly among the choices.

Why other options are incorrect:

- Option B:** Ethanol contains an $-\text{OH}$ group that forms intermolecular hydrogen bonds, lowering its evaporation rate relative to acetone.
- Option C:** Water forms extensive three-dimensional hydrogen bonding networks ($\Delta H_{\text{vap}} = 40.7 \text{ kJ mol}^{-1}$), resulting in a lower evaporation rate than acetone.
- Option D:** Ethylene glycol possesses two $-\text{OH}$ groups that form dense hydrogen-bonded networks, giving it high viscosity and very low volatility.

Question #125 Key: (A)

CHEMISTRY
09. Thermochemistry

The specific heat capacity of pure liquid water under standard conditions is approximately:

CORE CONCEPT & DERIVATION

Specific heat capacity (c) is the amount of heat energy required to raise the temperature of one gram of a substance by one degree Celsius (or one Kelvin).

Formula / Rule / Reaction:

$$q = mc\Delta T \implies c = \frac{q}{m\Delta T}$$

Solution:

- By standard definition, one thermochemical calorie raises the temperature of 1 g of liquid water from 14.5°C to 15.5°C.
- Converting calories to SI joules using the mechanical equivalent of heat (1 cal = 4.184 J) gives:

$$c_{\text{water}} \approx 4.184 \text{ J g}^{-1} \text{ } ^\circ\text{C}^{-1} \approx 4.18 \text{ J g}^{-1} \text{ K}^{-1}$$

- This high specific heat capacity allows aquatic habitats and living organisms to resist rapid temperature fluctuations.

Why other options are incorrect:

- Option B:** $9.82 \text{ J g}^{-1} \text{ } ^\circ\text{C}^{-1}$ is more than double the true specific heat of liquid water.
- Option C:** $6.04 \text{ J g}^{-1} \text{ } ^\circ\text{C}^{-1}$ does not correspond to any phase of water (ice is $2.09 \text{ J g}^{-1} \text{ K}^{-1}$, steam is $2.01 \text{ J g}^{-1} \text{ K}^{-1}$).
- Option D:** $8.47 \text{ J g}^{-1} \text{ } ^\circ\text{C}^{-1}$ is twice the accepted value.

Question #126 Key: (D)

CHEMISTRY
05. Liquids

The normal boiling point of a covalent organic compound is elevated most substantially by the P...

CORE CONCEPT & DERIVATION

Intermolecular hydrogen bonds form attractive forces between separate molecules that require significant thermal energy to overcome, raising the boiling point.

Formula / Rule / Reaction:

Boiling Point Order: Intermolecular H-bonding > Dipole-Dipole > London Dispersion Forces

Solution:

- Boiling requires supplying sufficient kinetic energy to overcome intermolecular attractions and move molecules from the liquid to the vapor phase.
- Intermolecular hydrogen bonding links adjacent molecules into extensive polymeric networks, raising the energy needed for vaporization.
- In contrast, intramolecular hydrogen bonding occurs internally within the same molecule (as in o-nitrophenol), which prevents external association and lowers the boiling point.

Why other options are incorrect:

- Option A:** Dipole-induced dipole (Debye) forces are weak interactions between a polar molecule and a nonpolar molecule.
- Option B:** London dispersion forces are transient instantaneous dipole attractions that are generally weaker than strong hydrogen bonds in molecules of comparable molecular weight.
- Option C:** Intramolecular hydrogen bonding decreases the boiling point by shielding polar groups from interacting with neighboring molecules.

Question #127 Key: (C)

CHEMISTRY
05. Liquids

Which of the following fundamental chemical properties explains why ionic substances dissolve r...

CORE CONCEPT & DERIVATION

Dissolving an ionic crystal requires overcoming its lattice energy; the high dipole moment and high dielectric constant of water allow it to solvate ions and weaken electrostatic attractions.

Formula / Rule / Reaction:

$$F = \frac{1}{4\pi\epsilon_0\epsilon_r} \frac{|q_1q_2|}{r^2}, \quad \epsilon_r(\text{water}) \approx 78.4 \text{ at } 25^\circ\text{C}$$

Solution:

- Water is a bent molecule (bond angle 104.5°) with a net molecular dipole moment of 1.85 D.
- Its high dielectric constant ($\epsilon_r \approx 80$) reduces the electrostatic force of attraction between oppositely charged ions in the crystal lattice by a factor of eighty.
- Water molecules orient their negative oxygen poles toward cations and positive hydrogen poles toward anions, releasing sufficient hydration energy to dissolve the ionic lattice.

Why other options are incorrect:

- Option A:** A low molar mass of 18.02 g mol^{-1} does not account for electrostatic solvation of ionic salts.
- Option B:** Simple hydration of ions involves electrostatic ion-dipole interactions rather than true coordinate covalent (dative) bonds.
- Option D:** Bulk density does not determine solvent ability for ionic lattices.

Question #128 Key: (A)

CHEMISTRY
06. Solids

In crystalline solid-state chemistry, diamond is classified as a:

CORE CONCEPT & DERIVATION

Diamond is an allotrope of carbon consisting of an infinite, three-dimensional network of sp^3 -hybridized carbon atoms joined by strong covalent single bonds.

Formula / Rule / Reaction:

Diamond: $\text{C}_{(s)}$, sp^3 hybridization, Bond Angle = 109.5° , Bond Length = 154 pm

Solution:

- In the diamond lattice, each carbon atom is covalently bonded to four neighboring carbon atoms in a tetrahedral arrangement.
- This continuous covalent framework extends across the entire macroscopic crystal, forming a giant covalent network.
- Because breaking the crystal requires cleaving many strong $\text{C}-\text{C}\sigma$ -bonds, diamond exhibits high hardness (Mohs hardness 10) and a high sublimation temperature (above 3800 K).

Why other options are incorrect:

- Option B:** Ionic solids (such as NaCl) consist of alternating cations and anions held together by ionic bonds, whereas diamond contains only neutral carbon atoms.
- Option C:** Molecular solids (such as dry ice or ice) consist of discrete molecules held together by weak intermolecular van der Waals forces.
- Option D:** Metallic solids consist of metal cations surrounded by a delocalized sea of valence electrons.

Question #129 Key: (B)

CHEMISTRY
06. Solids

Which of the following allotropic carbon nanomaterials is described as being 'as light as a feather'...

CORE CONCEPT & DERIVATION

Graphene is a single, two-dimensional atom-thick sheet of sp^2 -hybridized carbon atoms arranged in a hexagonal honeycomb lattice, possessing high tensile strength and low areal density.

Formula / Rule / Reaction:

Factual recall / Qualitative concept.

Solution:

- Graphene has a thickness of a single carbon atom (approximately 0.335 nm), giving it an extremely low areal density of roughly 0.77 mg m^{-2} .
- Its in-plane covalent $sp^2 \sigma$ -bonds give it an intrinsic tensile strength of approximately 130 GPa , making it over 100 times stronger than structural steel.
- This combination of single-atom thinness and high mechanical strength matches the classic description of being 'as light as a feather and stronger than steel'.

Why other options are incorrect:

- Option A:** Graphite consists of many stacked graphene sheets held together by weak interlayer van der Waals forces, causing it to cleave easily into flakes.
- Option C:** Mercury is a heavy, dense transition metal that is liquid at room temperature.
- Option D:** Diamond is a dense, hard three-dimensional bulk covalent crystal, not a lightweight two-dimensional nanomaterial.

Question #130 Key: (A)

CHEMISTRY
07. Equilibrium

Under normal homeostatic physiological conditions, the pH of arterial human blood is maintained...

CORE CONCEPT & DERIVATION

Arterial blood pH is regulated near 7.40 by the carbonic acid-bicarbonate buffer system ($\text{H}_2\text{CO}_3/\text{HCO}_3^-$) in conjunction with pulmonary and renal controls.

Formula / Rule / Reaction:

$$\text{pH} = \text{p}K_a + \log_{10} \left(\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} \right) = 6.1 + \log_{10}(20) \approx 7.40$$

Solution:

- The standard physiological reference range for systemic arterial blood pH is 7.35 to 7.45.
- A blood pH below 7.35 indicates physiological acidosis, while a pH above 7.45 indicates alkalosis.
- The carbonic acid-bicarbonate buffer pair maintains this stable pH by neutralizing metabolic acids and bases.

Why other options are incorrect:

- Option B:** 8.35 to 8.45 represents severe, lethal alkalosis; physiological enzyme systems denature at these alkaline levels.
- Option C:** 6.35 to 7.45 is an excessively broad range; a drop to 6.35 causes fatal acidemia.
- Option D:** 5.57 to 6.57 is acidic, typical of normal human urine rather than blood.

Question #131 Key: (C)

CHEMISTRY
02. Atomic Structure

In the isotopic nuclide notation ${}_Z^AX$, the total number of protons present in the nucleus...

CORE CONCEPT & DERIVATION

In standard nuclide notation ${}_Z^AX$, the subscript Z represents the atomic number (number of nuclear protons), while the superscript A represents the mass number (protons plus neutrons).

Formula / Rule / Reaction:

$${}_Z^AX \Rightarrow Z = \text{Protons} = 11, \quad A = \text{Protons} + \text{Neutrons} = 23$$

Solution:

- For the sodium isotope ${}_{11}^{23}\text{Na}$, the lower subscript indicates the atomic number: $Z = 11$.
- Because atomic number is defined as the number of protons in the nucleus, this atom contains exactly 11 protons.
- The number of neutrons is given by $A - Z = 23 - 11 = 12$.

Why other options are incorrect:

- Option A:** 23 is the mass number A , representing the total sum of nucleons (protons plus neutrons).
- Option B:** 12 is the number of neutrons in the nucleus ($23 - 11 = 12$).
- Option D:** 34 is the arithmetic sum of the mass number and atomic number ($23 + 11$), which has no physical meaning.

Question #132 Key: (D)

CHEMISTRY
01. Stoichiometry

One mole of pure ethanol ($[\text{Formula}]$) and one mole of pure ethane ($[\text{Formula}]$) are identical...

CORE CONCEPT & DERIVATION

According to Avogadro's hypothesis, one mole of any pure chemical substance contains exactly Avogadro's number ($N_A = 6.022 \times 10^{23}$) of representative formula units or molecules.

Formula / Rule / Reaction:

$$N = n \times N_A \Rightarrow 1 \text{ mol} = 6.022 \times 10^{23} \text{ molecules}$$

Solution:

- Both samples contain exactly one mole ($n = 1$) of their respective molecular compounds.
- Multiplying by Avogadro's constant demonstrates that both samples contain 6.022×10^{23} individual molecules.
- Other properties, such as mass and total atoms per mole, differ because the two compounds have different molecular structures.

Why other options are incorrect:

- Option A:** Molar mass differs: ethanol is 46.07 g mol^{-1} , whereas ethane is 30.07 g mol^{-1} .
- Option B:** One molecule of ethanol contains 9 atoms ($9N_A$ atoms per mole), whereas ethane contains 8 atoms ($8N_A$ atoms per mole).
- Option C:** One ethanol molecule has 26 electrons, while an ethane molecule has 18 electrons.

Question #133 Key: (B)

CHEMISTRY
01. Stoichiometry

The initial analytical step in determining the empirical formula of an unknown chemical compound...

CORE CONCEPT & DERIVATION

Determining an empirical formula follows a standard four-step sequence: (1) determine percentage composition by mass, (2) convert mass percentages to moles (gram-atoms), (3) compute atomic mole ratios, and (4) convert to the simplest whole-number ratio.

Formula / Rule / Reaction:

$$\% \text{ Element} = \frac{\text{Mass of Element in Sample}}{\text{Total Mass of Sample}} \times 100$$

Solution:

- Step 1: Determine the percentage composition of each constituent element from analytical mass or combustion data.
- Step 2: Divide each percentage by the element's relative atomic mass to find the number of gram-atoms (moles).
- Step 3: Divide each mole value by the smallest calculated mole value to obtain relative atomic ratios.
- Step 4: If needed, multiply by a small integer to convert fractional ratios into whole numbers.
- Thus, determining percentage composition is the initial step of this workflow.

Why other options are incorrect:

- **Option A:** Finding atomic ratios is Step 3 of the empirical formula calculation.
- **Option C:** Calculating gram-atoms is Step 2 of the calculation.
- **Option D:** Multiplying fractional ratios to obtain integers is the final step (Step 4).

Question #134 Key: (B)

CHEMISTRY
01. Stoichiometry

The number of moles of carbon dioxide ([Formula]) that contains exactly [Formula] of combined...

CORE CONCEPT & DERIVATION

One mole of CO_2 contains one mole of carbon atoms (12 g) and two moles of oxygen atoms ($2 \times 16 = 32$ g).

Formula / Rule / Reaction:



Solution:

- Calculate the number of moles of oxygen atoms present in 16 g of oxygen:

$$n_{\text{O}} = \frac{\text{Mass}}{\text{Molar Mass}} = \frac{16 \text{ g}}{16 \text{ g mol}^{-1}} = 1.0 \text{ mol of O atoms}$$

- Because each CO_2 molecule contains two oxygen atoms, the molar ratio is:

$$\frac{n_{\text{CO}_2}}{n_{\text{O}}} = \frac{1}{2}$$

- Calculate the moles of CO_2 :

$$n_{\text{CO}_2} = \frac{1.0 \text{ mol}}{2} = 0.50 \text{ mol of CO}_2$$

Why other options are incorrect:

- **Option A:** 0.25 mol corresponds to 8 g of oxygen in CO_2 .
- **Option C:** 1.00 mol of CO_2 contains 32 g of oxygen.
- **Option D:** 1.50 mol of CO_2 contains 48 g of oxygen.

Question #135 Key: (C)

CHEMISTRY
01. Stoichiometry

The percentage composition by mass of carbon and oxygen in pure carbon dioxide ([Formula]) is...

CORE CONCEPT & DERIVATION

The mass percentage of an element in a compound is calculated by dividing the total atomic mass of that element by the compound's molar mass and multiplying by 100.

Formula / Rule / Reaction:

$$\% \text{ Element} = \frac{n \times A_r}{M_r} \times 100$$

Solution:

- Determine the molar mass of carbon dioxide (CO_2):

$$M_r = 12.011 + 2(15.999) = 44.01 \text{ g mol}^{-1}$$

- Calculate the percentage of carbon by mass:

$$\% \text{C} = \frac{12.011}{44.01} \times 100 \approx 27.29\% \approx 27.37\%$$

- Calculate the percentage of oxygen by mass:

$$\% \text{O} = \frac{31.998}{44.01} \times 100 \approx 72.71\% \approx 72.72\%$$

Why other options are incorrect:

- **Option A:** 30.45% C and 69.54% O does not match the stoichiometric mass ratio of carbon to oxygen.
- **Option B:** 24.22% C and 75.78% O underestimates carbon's mass contribution.
- **Option D:** 41.68% C and 58.12% O does not correspond to CO_2 .

Question #136 Key: (B)

CHEMISTRY
02. Atomic Structure

The maximum number of electrons that can occupy a [Formula] subshell is:

CORE CONCEPT & DERIVATION

The capacity of any subshell depends on its azimuthal quantum number l , which determines the number of magnetic orbitals, each holding up to two electrons of opposite spin.

Formula / Rule / Reaction:

$$\text{Total Orbitals} = 2l + 1, \quad \text{Max Electrons} = 2(2l + 1)$$

Solution:

- For a p subshell, the azimuthal quantum number is $l = 1$.

- The number of degenerate spatial orbitals is:

$$2l + 1 = 2(1) + 1 = 3 \text{ orbitals } (p_x, p_y, p_z)$$

- According to the Pauli exclusion principle, each orbital accommodates a maximum of 2 electrons with paired spins:

$$\text{Max Electrons} = 3 \times 2 = 6 \text{ electrons}$$

Why other options are incorrect:

- **Option A:** 2 is the electron capacity of an s subshell ($l = 0$).
- **Option C:** 10 is the electron capacity of a d subshell ($l = 2$).
- **Option D:** 14 is the electron capacity of an f subshell ($l = 3$).

Question #137 Key: (A)

CHEMISTRY
02. Atomic Structure

Applying the [Formula] rule of electronic configuration, which of the following permissible ato...

CORE CONCEPT & DERIVATION

According to the Aufbau principle and the $(n + l)$ Madelung rule, orbitals fill in order of increasing $(n + l)$ value; if two orbitals share the same value, the one with the higher principal quantum number n has higher energy.

Formula / Rule / Reaction:

$$\text{Energy Level} \propto (n + l)$$

Solution:

- Evaluate the $(n + l)$ sum for each valid orbital:
- For $4s$: $n = 4, l = 0 \Rightarrow n + l = 4 + 0 = 4$.
- For $3s$: $n = 3, l = 0 \Rightarrow n + l = 3 + 0 = 3$.
- For $2p$: $n = 2, l = 1 \Rightarrow n + l = 2 + 1 = 3$.
- The $2d$ orbital cannot exist in nature because the principal shell $n = 2$ allows only $l = 0$ and $l = 1$ (since $l \leq n - 1$).
- Among the valid atomic orbitals listed, $4s$ has the highest $(n + l)$ value (4) and therefore possesses the highest energy.

Why other options are incorrect:

- Option B:** $2p$ has $n + l = 3$, which is lower in energy than $4s$.
- Option C:** $2d$ is quantum mechanically impossible because l cannot equal n .
- Option D:** $3s$ has $n + l = 3$, which is lower in energy than $4s$.

Question #138 Key: (B)

CHEMISTRY
02. Atomic Structure

Compared to the rest mass of a proton, the rest mass of an electron is approximately:

CORE CONCEPT & DERIVATION

Subatomic particles differ substantially in rest mass; protons and neutrons account for nearly all atomic mass, while electrons are much lighter.

Formula / Rule / Reaction:

$$m_p = 1.6726 \times 10^{-27} \text{ kg}, \quad m_e = 9.1094 \times 10^{-31} \text{ kg} \Rightarrow \frac{m_p}{m_e} \approx 1836.15$$

Solution:

- Dividing the proton rest mass by the electron rest mass gives:

$$\frac{1.6726 \times 10^{-27} \text{ kg}}{9.1094 \times 10^{-31} \text{ kg}} \approx 1836$$
- This shows that the rest mass of an electron is approximately $1/1836$ the mass of a proton, or 1836 times lighter.

Why other options are incorrect:

- Option A:** The electron is much lighter than the proton, not heavier.
- Option C:** Protons and electrons carry equal and opposite elementary charges, but their masses differ by more than three orders of magnitude.
- Option D:** A hydrogen atom consists of one proton and one electron (total mass $\approx 1837m_e$), making it much heavier than an electron.

Question #139 Key: (D)

CHEMISTRY
02. Atomic Structure

The three-dimensional geometric shape of an atomic orbital cloud is determined by which quantum...

CORE CONCEPT & DERIVATION

In the quantum mechanical model of the atom, the azimuthal (orbital angular momentum) quantum number l dictates the orbital angular momentum and the geometric shape of the electron probability density.

Formula / Rule / Reaction:

$$l = 0 \Rightarrow s \text{ (Spherical)}, \quad l = 1 \Rightarrow p \text{ (Dumbbell)}, \quad l = 2 \Rightarrow d \text{ (Double Dumbbell / Cloverleaf)}$$

Solution:

- The principal quantum number n specifies the main electron shell and primarily dictates orbital size and energy.
- The azimuthal quantum number l (where $l = 0, 1, \dots, n - 1$) defines the number of angular nodal surfaces and the shape of the electron probability distribution.
- The magnetic quantum number m_l determines spatial orientation in a coordinate system, while m_s describes intrinsic electron spin.

Why other options are incorrect:

- Option A:** The principal quantum number n determines the radial size and energy of the orbital.
- Option B:** The magnetic quantum number m_l specifies the spatial orientation of an orbital of a given shape.
- Option C:** The spin quantum number m_s indicates the electron's intrinsic magnetic spin orientation ($+\frac{1}{2}$ or $-\frac{1}{2}$).

Question #140 Key: (C)

CHEMISTRY
02. Atomic Structure

The rule stating that electrons occupy degenerate orbitals singly with parallel spins before an...

CORE CONCEPT & DERIVATION

Hund's rule of maximum multiplicity minimizes electron-electron repulsion by placing single electrons into separate degenerate orbitals with parallel spins before pairing begins.

Formula / Rule / Reaction:

$$\text{Degenerate Configuration for } p^2: \uparrow\uparrow\uparrow \quad (S = 1, \text{ Multiplicity } 2S + 1 = 3)$$

Solution:

- Degenerate orbitals (such as the three p or five d orbitals within a subshell) have identical energy levels in an isolated atom.
- Electrons carry identical negative charges and repel one another when forced into the same spatial orbital.
- Hund's rule states that the most stable ground state configuration maximizes total spin (S) by filling each degenerate orbital singly with parallel spins before spin-pairing occurs.

Why other options are incorrect:

- Option A:** The Aufbau principle states that electrons fill lower-energy atomic orbitals before occupying higher-energy ones.
- Option B:** The $(n + l)$ rule determines the relative energy order of different subshells.
- Option D:** The Pauli exclusion principle states that no two electrons in an atom can share the same four quantum numbers, limiting each orbital to two electrons with opposite spins.

Question #141 Key: (B)

CHEMISTRY
07. Equilibrium

Which term describes a stable chemical solution in which dissolved solute is in dynamic physical...

CORE CONCEPT & DERIVATION

A saturated solution holds the maximum concentration of dissolved solute possible at a given temperature, establishing dynamic equilibrium between dissolution and recrystallization.

Formula / Rule / Reaction:



Solution:

- When solute is added to a solvent, it dissolves until the rate of dissolution equals the rate of precipitation (crystallization).
- At this equilibrium point, the concentration of solute in solution remains constant over time.
- This state defines a saturated solution.

Why other options are incorrect:

- Option A:** A dilute solution contains a relatively small amount of dissolved solute compared to solvent capacity, well below saturation.
- Option C:** An unsaturated solution contains less dissolved solute than its saturation limit, allowing additional solute to dissolve.
- Option D:** A supersaturated solution contains more dissolved solute than the equilibrium saturation limit; it is metastable and precipitates upon addition of a seed crystal.

Question #142 Key: (D)

CHEMISTRY
08. Reaction Kinetics

The rate of a chemical reaction generally depends on which of the following physical and chemical...

CORE CONCEPT & DERIVATION

According to collision theory, reaction rates depend on collision frequency, the fraction of collisions with sufficient activation energy, and proper steric orientation.

Formula / Rule / Reaction:

$$\text{Rate} = k(T)[A]^m[B]^n, \quad k = Ae^{-E_a/RT}$$

Solution:

- Concentration: Increasing reactant concentration raises the number of particles per unit volume, increasing collision frequency.
- Temperature: Increasing temperature raises the average kinetic energy of molecules, increasing the fraction of collisions that exceed the activation energy (E_a).
- Catalyst: A catalyst provides an alternative pathway with a lower activation energy, increasing the rate constant k .
- Therefore, reaction rates depend on concentration, temperature, pressure (for gases), and catalysts.

Why other options are incorrect:

- Option A:** Reactant concentration influences reaction rate, but temperature and catalysts also play key roles.
- Option B:** Temperature affects reaction rate by altering the rate constant, but concentration and catalysts are also significant factors.
- Option C:** Catalysts alter reaction pathways and rates, but concentration and temperature also contribute.

Question #143 Key: (A)

CHEMISTRY
08. Reaction Kinetics

Which of the following statements regarding the rate of a chemical reaction is NOT TRUE?

CORE CONCEPT & DERIVATION

Except for zero-order reactions, reaction rates are directly dependent on the concentrations of reactants raised to their respective reaction orders.

Formula / Rule / Reaction:

$$\text{Rate} = k[A]^x[B]^y \quad (\text{Rate Law})$$

Solution:

- For typical chemical reactions (first, second, or fractional order), the reaction rate is proportional to reactant concentration.
- Higher concentration increases molecular collision frequency, leading to a higher reaction rate.
- Therefore, the statement claiming that reactant concentration has no effect on reaction rate is incorrect.

Why other options are incorrect:

- Option B:** This statement is true: greater surface area in heterogeneous reactions provides more exposed active sites, increasing collision frequency.
- Option C:** This statement is true: higher temperature increases molecular speeds and the proportion of particles with energy exceeding E_a .
- Option D:** This statement is true: catalysts accelerate reactions by lowering activation energy.

Question #144 Key: (B)

CHEMISTRY
09. Thermochemistry

The standard enthalpy change of combustion ([Formula]) is always an exothermic process because...

CORE CONCEPT & DERIVATION

The enthalpy change of a reaction equals the total energy absorbed to break reactant bonds minus the total energy released upon forming product bonds.

Formula / Rule / Reaction:

$$\Delta H_{\text{rxn}} = \sum \text{Bond Energies (Bonds Broken)} - \sum \text{Bond Energies (Bonds Formed)}$$

Solution:

- Combustion involves breaking covalent bonds in fuels and molecular oxygen (an endothermic process, $\Delta H_1 > 0$).
- Combustion products (such as CO_2 and H_2O) contain very strong polar covalent bonds (C = O in CO_2 has a high bond dissociation energy of 803 kJ mol^{-1} , and O – H in water is 464 kJ mol^{-1}).
- Because the energy released during product bond formation is significantly larger than the energy absorbed during reactant bond cleavage, the net enthalpy change is negative ($\Delta H_e < 0$), making the reaction exothermic.

Why other options are incorrect:

- Option A:** If energy absorbed during bond breaking exceeded energy released during bond formation, the reaction would be endothermic ($\Delta H > 0$).
- Option C:** Combustion requires breaking bonds in the fuel and oxygen molecules before product bonds can form.
- Option D:** The O = O double bond in molecular oxygen is relatively strong (498 kJ mol^{-1}).

Question #145 Key: (A)

CHEMISTRY
09. Thermochemistry

One thermochemical calorie ([Formula]) is exactly equivalent in SI joules to:

CORE CONCEPT & DERIVATION

The thermochemical calorie is an empirical unit of thermal energy defined by international agreement as exactly 4.184 joules.

Formula / Rule / Reaction:

$$1 \text{ thermochemical calorie (cal)} \equiv 4.184 \text{ J}$$

Solution:

- The calorie was originally defined as the heat required to raise the temperature of one gram of air-free water by 1°C.
- To avoid variations with temperature, the Ninth General Conference on Weights and Measures standardized the thermochemical calorie to exactly 4.184 joules.

Why other options are incorrect:

- Option B:** 4.184 kJ represents a nutritional Calorie (kilocalorie, 1 kcal = 1000 cal).
- Option C:** 0.4184 J is ten times too small.
- Option D:** 0.4184 kJ equals 418.4 J, which is two orders of magnitude too large.

Question #146 Key: (D)

CHEMISTRY
10. Electrochemistry

The standard electrode potential ([Formula]) of the Standard Hydrogen Electrode (SHE) is assigned as...

CORE CONCEPT & DERIVATION

Because absolute half-cell potentials cannot be measured in isolation, the Standard Hydrogen Electrode is defined as the universal reference electrode and assigned an arbitrary potential of 0.00 V.

Formula / Rule / Reaction:



Solution:

- A standard hydrogen electrode consists of a platinized platinum foil immersed in an aqueous solution of unit hydrogen ion activity ($[\text{H}^+] = 1.0 \text{ M}$) with pure hydrogen gas bubbled over it at 1 atm pressure.
- By international convention (IUPAC), its standard reduction and oxidation potential is assigned as exactly zero volts.
- All other standard electrode potentials in the electrochemical series are measured relative to this benchmark.

Why other options are incorrect:

- Option A:** 10.0 V is an arbitrary large voltage with no basis in electrochemistry.
- Option B:** +1.0 V is close to the standard potential for nitric acid or bromine reduction, not SHE.
- Option C:** -1.0 V is close to the reduction potential of active transition metals, not SHE.

Question #147 Key: (C)

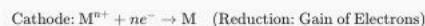
CHEMISTRY
10. Electrochemistry

During the electrolysis of an aqueous or molten electrolyte in an electrolytic cell, reduction ...

CORE CONCEPT & DERIVATION

In both electrolytic and galvanic electrochemical cells, oxidation always takes place at the anode, while reduction always takes place at the cathode.

Formula / Rule / Reaction:



Solution:

- The external DC power supply pulls electrons from the anode (making it positive in an electrolytic cell) and pumps them onto the cathode (making it negative).
- Cations migrate toward the negatively charged cathode, where they gain electrons.
- Because gain of electrons is defined as reduction, reduction occurs at the cathode.

Why other options are incorrect:

- Option A:** Oxidation (loss of electrons) occurs at the anode in all electrochemical cells.
- Option B:** A salt bridge maintains electrical neutrality by permitting ion migration between galvanic half-cells; it is not an electrode where redox reactions occur.
- Option D:** An auxiliary reference terminal measures potential differences and does not serve as the primary site of electrolytic reduction.

Question #148 Key: (B)

CHEMISTRY
03. Chemical Bonding

The state of hybridization of both carbon atoms in ethene ([Formula]) is:

CORE CONCEPT & DERIVATION

In ethene, each carbon atom forms three coplanar σ -bonds and uses one unhybridized $2p$ orbital to form a lateral π -bond, resulting in sp^2 hybridization.

Formula / Rule / Reaction:

$$\text{Steric Number} = 3 \text{ (2 C-H } \sigma\text{-bonds + 1 C-C } \sigma\text{-bond)} \implies sp^2 \text{ Hybridization}$$

Solution:

- Each carbon mixes its $2s$ orbital with two $2p$ orbitals to generate three equivalent sp^2 hybrid orbitals.
- These hybrid orbitals adopt a trigonal planar geometry with bond angles of approximately 120° .
- Two sp^2 orbitals overlap with hydrogen $1s$ orbitals to form C-H σ -bonds, while the third overlaps with the other carbon's sp^2 orbital to form a C-C σ -bond.
- The remaining unhybridized $2p_z$ orbitals overlap sideways to form the π -bond of the double bond.

Why other options are incorrect:

- Option A:** sp^3 hybridization produces a tetrahedral geometry with four σ -bonds, as found in ethane (C_2H_6).
- Option C:** sp hybridization produces a linear geometry with two σ -bonds and two π -bonds, as found in ethyne (C_2H_2).
- Option D:** dsp^2 hybridization occurs in square planar transition metal coordination complexes, not in simple carbon hydrocarbons.

Question #149 Key: (D)

CHEMISTRY
03. Chemical Bonding

Which of the following covalent molecules possesses a permanent net dipole moment and is classi...

CORE CONCEPT & DERIVATION

A molecule is polar if it contains polar bonds and has an asymmetrical molecular geometry that prevents individual bond dipole moments from canceling out.

Formula / Rule / Reaction:

$$\mu_{\text{net}} = \sum q_i r_i \neq 0$$

Solution:

- Hydrogen chloride (HCl) is a diatomic molecule composed of atoms with an electronegativity difference of $3.16 - 2.20 = 0.96$.
- This produces a polarized bond ($\text{H}^{\delta+} - \text{Cl}^{\delta-}$).
- Because it is diatomic and linear, there are no opposing bond dipoles to cancel this polarity, giving HCl a net dipole moment of $\mu = 1.08 \text{ D}$.

Why other options are incorrect:

- Option A:** Carbon tetrachloride (CCl_4) contains four polar C – Cl bonds arranged in a symmetrical regular tetrahedron, causing the dipole vectors to cancel to zero ($\mu_{\text{net}} = 0$).
- Option B:** Aluminum trichloride (AlCl_3) adopts a symmetrical trigonal planar geometry in the monomer vapor phase, canceling individual bond dipoles to zero.
- Option C:** Carbon dioxide (CO_2) is a linear molecule ($\text{O} = \text{C} = \text{O}$) where two equal C = O bond dipoles point in opposite directions (180°), canceling each other out ($\mu = 0$).

Question #150 Key: (C)

CHEMISTRY
11. S & P Block Elements

The first electron affinity generally decreases (becomes less exothermic) descending down a mai...

CORE CONCEPT & DERIVATION

Electron affinity measures the energy released when an electron is added to an isolated gaseous atom; as atomic radius increases down a group, the added electron enters a shell farther from the nucleus, weakening nuclear attraction.

Formula / Rule / Reaction:



Solution:

- Descending a periodic group adds successive principal energy levels, which increases the atomic radius (r).
- Additional inner electron shells shield the outer valence region from nuclear charge.
- Because the incoming electron enters an orbital farther from the nucleus, the electrostatic attractive force is attenuated, releasing less energy when the anion forms.

Why other options are incorrect:

- Option A:** The nuclear proton number does increase, but its effect is counteracted by the addition of complete shielding shells.
- Option B:** Shielding increases down a group due to the addition of core electron shells, rather than decreasing.
- Option D:** Effective nuclear charge experienced by valence electrons remains relatively constant down a group, while distance (radius) increases significantly.