TIFR GS Biology

Sample Paper – 1

Duration: 180 Minutes **Maximum Marks: 80**

Instructions

- This paper contains **60 Multiple Choice Questions** (single correct answer) modelled on the **JGEEBILS** (TIFR Graduate School Biology) entrance examination.
- Questions are in **4 sections**: General, Physics, Chemistry, and Biology. Each section has **Sub-section A** (10 questions, 1 mark each) and **Sub-section B** (5 questions, 2 marks each).
- **Sub-section A:** $+1$ for correct answer; -0.5 for incorrect answer; 0 for unattempted.
- **Sub-section B:** $+2$ for correct answer; **no negative marking**; 0 for unattempted.
- Only **one** option is correct per question. Read all options before answering.
- Syllabus: UG-level Biology, Physics, Chemistry, and General Science/Mathematics. No fixed topic list — questions test conceptual understanding, data reasoning, and experimental interpretation.
- Personal calculators, mobile phones, and electronic gadgets are strictly prohibited. Rough sheets will be provided.

GENERAL — Sub-section A (Q1–Q10: $+1$ mark each; -0.5 per wrong)

Q1. A principal of ₹5,000 is invested at a simple interest rate of 8% per annum for 3 years. What is the **total amount** (principal + interest) at the end of the period?

(A) ₹5,400

(B) ₹5,800

(C) ₹6,200

(D) ₹6,800

Q2. Two quantities a and b are in the ratio $3 : 7$, and their sum is 50. What is the value of a?

(A) 15

(B) 20

(C) 21

(D) 25

Q3. A train 200 m long crosses a platform 300 m long at a uniform speed of 72 km/h. How long does the train take to completely cross the platform?

(A) 20 seconds

(B) 25 seconds

(C) 30 seconds

(D) 35 seconds

Q4. For two sets A and B: $n(A) = 40$, $n(B) = 35$, and $n(A \cap B) = 15$. Using the inclusion-exclusion principle, what is $n(A \cup B)$?

(A) 75

(B) 70

(C) 65

(D) 60

Q5. A card is drawn at random from a standard well-shuffled deck of 52 cards. What is the probability that the card drawn is a **red face card**?

(A) $\frac{1}{13}$

(B) $\frac{1}{26}$

(C) $\frac{3}{26}$

(D) $\frac{2}{13}$

Q6. What is the next term in the geometric sequence: $2,\ 6,\ 18,\ 54,\ \ldots$?

(A) 162

(B) 108

(C) 216

(D) 144

Q7. In a certain coding scheme, **CAT** is written as **DBU** (each letter is replaced by the letter that follows it in the English alphabet). Using the same rule, how is **DOG** coded?

(A) EPN

(B) EPH

(C) DPH

(D) ENH

Q8. A biological sample has a mass of $3.2\,\mu$g (micrograms). Which of the following correctly expresses this mass in **grams** using scientific notation?

(A) 3.2×10^{-3} g

(B) 3.2×10^{-4} g

(C) 3.2×10^{-9} g

(D) 3.2×10^{-6} g

Q9. Complete the analogy: **Photosynthesis** is to **Chloroplast** as **Aerobic respiration** is to ________.

(A) Nucleus

(B) Ribosome

(C) Mitochondria

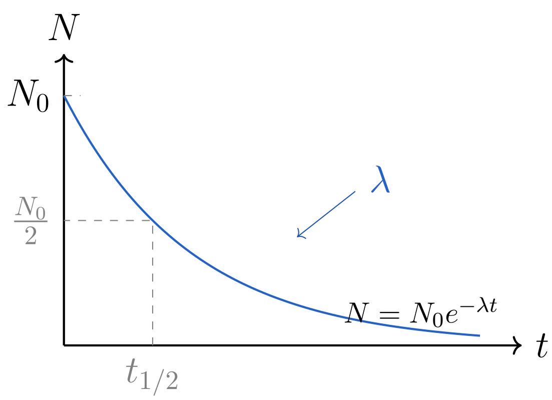
(D) Cell membrane

Q10. January 1, 2024 falls on a **Monday**. What day of the week is **March 15, 2024**? (Note: 2024 is a leap year.)

- **(A)** Friday
- **(B)** Saturday
- **(C)** Thursday
- **(D)** Sunday

GENERAL — Sub-section B (Q11–Q15: $+2$ marks each; no negative marking)

Q11. The graph below shows the decay of a radioactive sample, where N is the number of undecayed nuclei at time t, described by $N = N_0\,e^{-\lambda t}$.



What does the constant λ represent in this equation?

- **(A)** The initial number of undecayed nuclei, N_0
- **(B)** The decay constant: the probability of decay per nucleus per unit time
- **(C)** The half-life $t_{1/2}$ of the radioactive substance
- **(D)** The time required for all nuclei to decay completely

Q12. A researcher collects data on hair colour (black, brown, blonde) and eye colour (brown, blue, green) in a human population and wishes to determine whether hair colour and eye colour are *associated*. Which statistical test is most appropriate?

- **(A)** Student's t-test (unpaired) to compare means of the two groups

(B) Pearson's correlation coefficient to measure the strength of association

(C) Analysis of Variance (ANOVA) to compare variances across multiple groups

(D) Chi-square (χ^2) test of independence for categorical variables

Q13. A study reports the mean serum cholesterol of a sample as 190 mg/dL with a 95% confidence interval of $(183,\ 197)$ mg/dL. Which of the following is the **correct** interpretation of this interval?

(A) There is a 95% probability that the true population mean lies within this specific interval

(B) 95% of individual data values in the population fall between 183 and 197 mg/dL

(C) If the experiment were repeated many times, approximately 95% of the computed confidence intervals would contain the true population mean

(D) The sample mean has a 95% chance of being a correct estimate of the population mean

Q14. A study measures plant height and leaf area across 50 plants and computes a Pearson correlation coefficient of $r = +0.92$. What does this value indicate about the relationship between the two variables?

(A) A strong positive linear relationship: taller plants tend to have larger leaf areas

(B) A weak positive linear relationship with considerable scatter

(C) A perfect positive correlation implying that one variable *causes* the other

(D) A moderately positive but statistically insignificant association

Q15. The variance of a data set is computed to be **25**. What is the **standard deviation** of this data set?

(A) 12.5

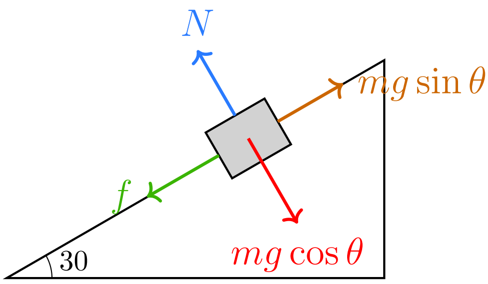
(B) 5

(C) 625

(D) 25

PHYSICS — Sub-section A (Q16–Q25: $+1$ mark each; -0.5 per wrong)

Q16. A block of mass $m = 5\,\text{kg}$ slides down a rough inclined plane at angle $\theta = 30$ from the horizontal. The coefficient of kinetic friction between the block and the surface is $\mu_k = 0.3$. The free-body diagram is shown below (take $g = 10\,\text{m/s}^2$, $\sin 30 = 0.5$, $\cos 30 \approx 0.87$).



incline surface

What is the acceleration of the block as it slides **down** the incline?

(A) $1.2\,\text{m/s}^2$

(B) $3.5\,\text{m/s}^2$

(C) $5.0\,\text{m/s}^2$

(D) $2.4\,\text{m/s}^2$

Q17. A projectile is launched with initial speed v_0 from ground level. The horizontal range is given by $R = \dfrac{v_0^2 \sin 2\theta}{g}$, where θ is the launch angle. For what value of θ is the horizontal range **maximum**?

(A) 30

(B) 60

(C) 45

(D) 90

Q18. A ball of mass $2\,\text{kg}$ is released from rest at a height $h = 10\,\text{m}$ above the ground. Assuming no air resistance and $g = 10\,\text{m/s}^2$, what is the **kinetic energy** of the ball just before it strikes the ground?

(A) $200\,\text{J}$

(B) $100\,\text{J}$

(C) $400\,\text{J}$

(D) $20\,\text{J}$

Q19. Water flows through a horizontal pipe that narrows from a wide section to a constricted section. According to **Bernoulli's principle**, what happens to the fluid **pressure** in the constricted (narrower) section where the fluid speed is greater?

(A) The pressure increases

(B) The pressure decreases

(C) The pressure remains unchanged

(D) The fluid density increases to conserve energy

Q20. A simple pendulum has a length $L = 4\,\text{m}$. Using the formula $T = 2\pi\sqrt{L/g}$ and $g = 10\,\text{m/s}^2$, what is the period T of small oscillations? (Use $\pi^2 \approx 10$.)

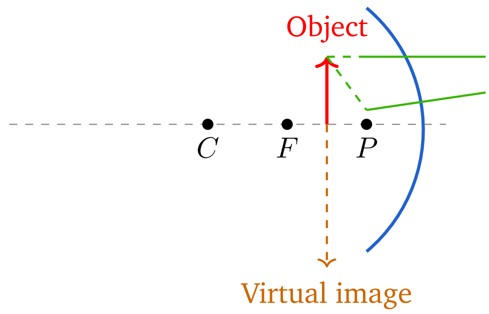
(A) $2\pi\,\text{s} \approx 6.28\,\text{s}$

(B) $\pi\,\text{s} \approx 3.14\,\text{s}$

(C) $2\,\text{s}$

(D) $4.0\,\text{s}$

Q21. The diagram below shows a **concave mirror** with principal focus F and pole P. An object (arrow) is placed **between** F **and** P (i.e. within the focal length).



Which of the following correctly describes the image formed when the object is placed between F and P of a concave mirror?

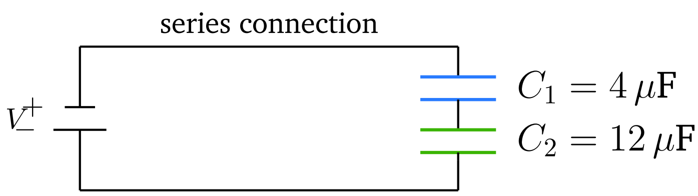
(A) Virtual, erect, and magnified (behind the mirror)

(B) Real, inverted, and magnified (in front of the mirror)

(C) Virtual, inverted, and diminished

(D) Real, erect, and same size as the object

Q22. Two capacitors, $C_1 = 4\,\mu\text{F}$ and $C_2 = 12\,\mu\text{F}$, are connected in **series** with a battery as shown below.



What is the **equivalent capacitance** C_{eq} of this combination? (Use $\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2}$.)

(A) $16\,\mu\text{F}$

(B) $48\,\mu\text{F}$

(C) $3\,\mu\text{F}$

(D) $8\,\mu\text{F}$

Q23. A wire of resistance R has its length **doubled** and its radius **halved** (while keeping the material the same). By what factor does the resistance change? (Use $R = \rho L/A$ where $A = \pi r^2$.)

(A) 2 times

(B) 8 times

(C) 4 times

(D) 16 times

Q24. The work function of a metal surface is $\phi = 2\,\text{eV}$. Using $hc = 1{,}240\,\text{eV nm}$, what is the **threshold wavelength** $\lambda_0 = hc/\phi$ below which photoelectric emission occurs?

(A) 248 nm

(B) 414 nm

(C) 496 nm

(D) 620 nm

Q25. In Rutherford's famous α-scattering experiment, a beam of α-particles was directed at a thin gold foil. The key observation was that the **vast majority** of α-particles passed straight through the foil with little or no deflection. What does this observation directly demonstrate?

(A) Most of the atom is empty space

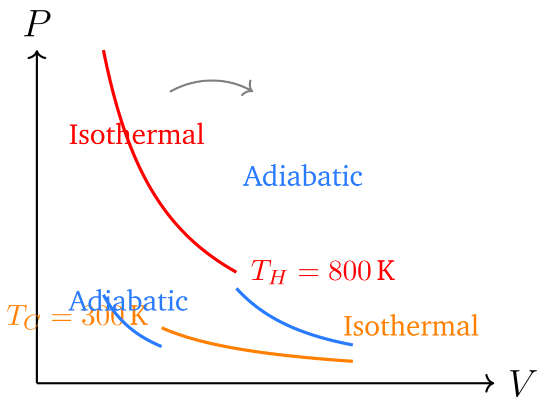
(B) Positive charge is uniformly distributed throughout the atom

(C) Electrons are distributed as a diffuse cloud throughout the atom

(D) The nucleus contains both protons and neutrons

PHYSICS — Sub-section B (Q26–Q30: $+2$ marks each; no negative marking)

Q26. The P–V diagram below represents one complete **Carnot cycle**: two isothermal processes (at temperatures T_H and T_C) alternating with two adiabatic processes.



For a Carnot engine operating between $T_H = 800\,\text{K}$ and $T_C = 300\,\text{K}$, the efficiency is $\eta = 1 - T_C/T_H$. What is η?

(A) 37.5%

(B) 50.0%

(C) 62.5%

(D) 75.0%

Q27. The diagram below shows a sound source moving to the **right** at speed $v_s = v/2$ (half the speed of sound v) toward a stationary observer. The wavefronts ahead of the source are compressed.

Using the Doppler formula $f_{\text{obs}} = f_s \dfrac{v}{v - v_s}$, what is the ratio f_{obs}/f_s when the source moves toward the observer at $v_s = v/2$?

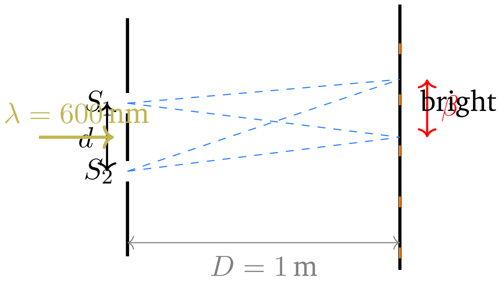
(A) 2

(B) 1.5

(C) 3

(D) 4

Q28. The diagram below shows a standard double-slit interference setup: two slits separated by $d = 0.5\,\text{mm}$, a screen at distance $D = 1\,\text{m}$, illuminated by monochromatic light of wavelength $\lambda = 600\,\text{nm}$.



Using $\beta = \lambda D/d$, what is the **fringe width** β?

(A) $0.6\,\text{mm}$

(B) $1.2\,\text{mm}$

(C) $2.4\,\text{mm}$

(D) $0.3\,\text{mm}$

Q29. In an RC circuit, a capacitor of capacitance $C = 10\,\mu\text{F}$ charges through a resistor of resistance $R = 100\,\text{k}\Omega$. What is the **time constant** $\tau = RC$ of this circuit?

(A) $0.1\,\text{s}$

(B) $0.5\,\text{s}$

(C) $2\,\text{s}$

(D) $1\,\text{s}$

Q30. The position of an electron is measured with an uncertainty of $\Delta x = 0.1\,\text{nm}$. Using the Heisenberg uncertainty relation $\Delta x\,\Delta p \geq \hbar/2$ (where $\hbar = 1.05 \times 10^{-34}\,\text{J s}$), what is the **minimum uncertainty** in the electron's momentum Δp_{min}?

(A) $1.05 \times 10^{-24}\,\text{kg m/s}$

(B) $5.25 \times 10^{-25}\,\text{kg m/s}$

(C) $2.10 \times 10^{-24}\,\text{kg m/s}$

(D) $1.05 \times 10^{-25}\,\text{kg m/s}$

CHEMISTRY — Sub-section A (Q31–Q40: $+1$ mark each; -0.5 per wrong)

Q31. 2-Butanol ($CH_3CH(OH)CH_2CH_3$) is heated with concentrated H_2SO_4. According to **Zaitsev's rule**, which alkene is the **major product** of this dehydration reaction?

- **(A)** But-2-ene (the more substituted, internal double bond)
- **(B)** But-1-ene (the less substituted, terminal double bond)
- **(C)** Buta-1,3-diene (conjugated diene by double elimination)
- **(D)** Cyclobutane (ring closure product)

Q32. Which combination of conditions is **required** for an E2 (bimolecular elimination) mechanism to operate efficiently?

- **(A)** A weak base and a syn-periplanar arrangement of the β-hydrogen and the leaving group
- **(B)** A strong nucleophile, gauche conformation, and a polar aprotic solvent
- **(C)** A strong base and an anti-periplanar arrangement of the β-hydrogen and the leaving group
- **(D)** An acid catalyst at high temperature proceeding via a carbocation (E1) intermediate

Q33. Using VSEPR theory, predict the **geometry** of PCl_5. Phosphorus in PCl_5 has five bonding pairs and no lone pairs of electrons.

- **(A)** Tetrahedral (sp^3)
- **(B)** Octahedral (sp^3d^2)
- **(C)** Square planar (dsp^2)
- **(D)** Trigonal bipyramidal (sp^3d)

Q34. In the Born-Haber cycle for the formation of NaCl (s) from its elements, which of the following steps is **exothermic** (releases energy)?

(A) Sublimation of sodium metal: $\mathrm{Na(s)} \longrightarrow \mathrm{Na(g)}$

(B) Electron affinity of chlorine: $\mathrm{Cl(g)} + \mathrm{e^-} \longrightarrow \mathrm{Cl^-(g)}$

(C) First ionisation energy of sodium: $\mathrm{Na(g)} \longrightarrow \mathrm{Na^+(g)} + \mathrm{e^-}$

(D) Bond dissociation of Cl_2: $\mathrm{Cl_2(g)} \longrightarrow 2\ \mathrm{Cl(g)}$

Q35. What is the **pH** of a $0.1\,\mathrm{M}$ aqueous solution of acetic acid ($K_a = 1.8 \times 10^{-5}$)? Use pH $= \frac{1}{2}(\mathrm{p}K_a + \mathrm{p}C)$, where $\mathrm{p}K_a = -\log K_a$ and $\mathrm{p}C = -\log[\text{acid}]$.

(A) 2.87

(B) 4.74

(C) 3.37

(D) 1.00

Q36. First ionisation energy *generally* increases from left to right across Period 2 of the periodic table. However, one element shows a **lower** first ionisation energy than the element immediately *preceding* it, because its $2p$ subshell contains a paired electron that experiences extra electron-electron repulsion. Which element is this?

(A) Lithium (Li)

(B) Boron (B)

(C) Oxygen (O)

(D) Neon (Ne)

Q37. What is the hybridisation of the carbon atom in carbon dioxide (CO_2), and what is the geometry of the molecule?

(A) sp^3; tetrahedral geometry

(B) sp^3d; trigonal bipyramidal geometry

(C) sp^2; bent (angular) geometry

(D) sp; linear geometry

Q38. Acetic acid reacts with ethanol in a Fischer esterification to give **ethyl**

acetate. Which conditions are used for this reaction?

(A) Aqueous NaOH at room temperature (saponification conditions)

(B) Concentrated H_2SO_4 as catalyst, with heating under reflux

(C) Anhydrous HCl gas in an aprotic solvent

(D) $AlCl_3$ catalyst (Friedel–Crafts acylation conditions)

Q39. In the **Fischer open-chain representation** of D-glucose, the carbonyl group at carbon-1 identifies glucose as a reducing sugar. Which functional group is present at carbon-1 in the open-chain form?

(A) An aldehyde ($-$CHO) group

(B) A ketone (C=O) group at carbon-2

(C) A carboxylic acid ($-$COOH) group

(D) A hydroxymethyl ($-CH_2OH$) group

Q40. Propanone (CH_3COCH_3) is treated with methyl magnesium bromide (CH_3MgBr) followed by aqueous work-up. What **type of alcohol** is the organic product?

(A) Primary alcohol

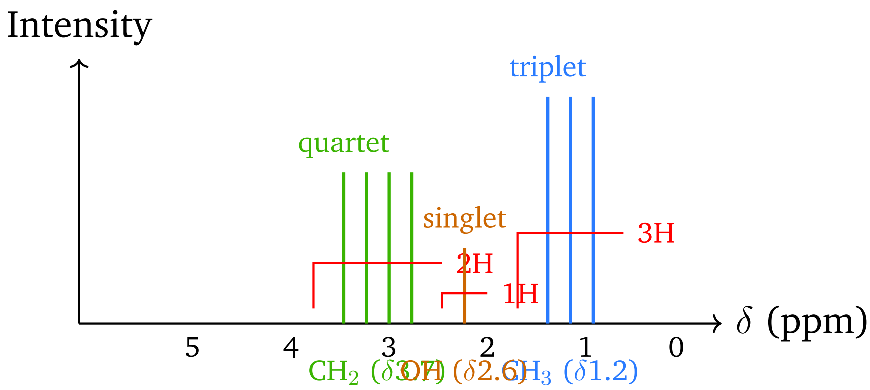
(B) Secondary alcohol

(C) Phenol

(D) Tertiary alcohol

CHEMISTRY — Sub-section B (Q41–Q45: $+2$ marks each; no negative marking)

Q41. The schematic ^{1}H NMR spectrum of ethanol (CH_3CH_2OH) below shows three signals. The peak areas (integrations) are proportional to the number of protons responsible for each signal.



Which signal has the **largest integrated area** (corresponding to the greatest number of equivalent protons)?

(A) The OH singlet at $\delta \approx 2.6$ (1 proton)

(B) The CH_3 triplet at $\delta \approx 1.2$ (3 protons)

(C) The CH_2 quartet at $\delta \approx 3.7$ (2 protons)

(D) The CH_3 and CH_2 signals have equal integration

Q42. Bond dissociation energies for selected bonds are: **N≡N** (945 kJ/mol), **C=C** (614 kJ/mol), **C–C** (347 kJ/mol), **C–H** (413 kJ/mol). Which bond listed above requires the **least energy** to break homolytically?

(A) C–C single bond (347 kJ/mol)

(B) C=C double bond (614 kJ/mol)

(C) N≡N triple bond (945 kJ/mol)

(D) C–H bond (413 kJ/mol)

Q43. Solid NaCl dissolves in water at room temperature to give Na^+ and Cl^- ions dispersed throughout the solution. What is the sign of the **entropy change** (ΔS) *for the system* during this process?

(A) $\Delta S < 0$; the highly ordered crystal is more disordered than the ionic solution

(B) $\Delta S = 0$; dissolution is an isoentropic (entropy-neutral) process

(C) $\Delta S > 0$; the ions become dispersed and disordered in solution, increasing entropy

(D) ΔS depends only on the lattice energy of NaCl, independent of the solvent

Q44. The Nernst equation relates the cell potential E to the standard potential E° and the reaction quotient Q:

$$E = E^\circ - \frac{RT}{nF} \ln Q$$

If $Q > 1$ (products are more abundant than reactants at a given instant), how does E compare to E°?

(A) $E > E^\circ$

(B) $E = E^\circ$

(C) E depends only on temperature, not on Q

(D) $E < E^\circ$

Q45. In Michaelis-Menten kinetics, the Michaelis constant K_m equals the substrate concentration at which the reaction velocity is $V_{\text{max}}/2$. What does a **low** K_m value imply about the enzyme?

(A) The enzyme requires a high substrate concentration to reach half-maximal velocity

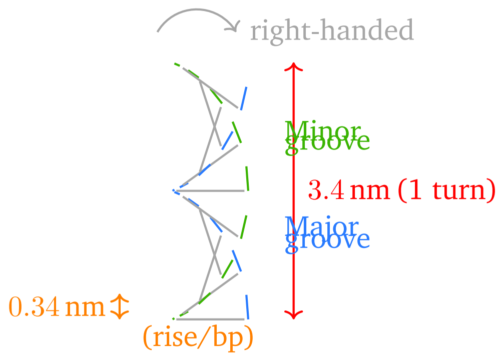
(B) The enzyme has a *high* affinity for its substrate and reaches $V_{\text{max}}/2$ at low substrate concentrations

(C) The enzyme has a low maximum velocity (V_{max})

(D) The enzyme is easily inhibited by competitive inhibitors at physiological substrate concentrations

BIOLOGY — Sub-section A (Q46–Q55: $+1$ mark each; -0.5 per wrong)

Q46. The schematic below represents the **B-form of DNA**, the predominant form under physiological conditions. It is a right-handed double helix with 10 base pairs per complete turn and a total rise per turn of 3.4 nm.



What is the **rise per base pair** (axial rise per residue) in B-DNA?

(A) 0.34 nm

(B) 0.20 nm

(C) 0.54 nm

(D) 3.4 nm (one full turn, not per base pair)

Q47. In the *E. coli* 70S ribosome, the small (30S) subunit contains 16S rRNA and ~21 proteins, while the large (50S) subunit contains 23S and 5S rRNAs. What is the primary function of the **30S subunit** during translation?

(A) Catalysing peptide bond formation (peptidyl transferase activity)

(B) Housing the peptide exit tunnel and binding the 5S rRNA

(C) Decoding the mRNA by facilitating codon–anticodon base-pairing at the A site

(D) Providing the GTPase activity that drives translocation along the mRNA

Q48. In the ubiquitin-proteasome pathway, proteins are tagged for degradation by attachment of polyubiquitin chains. To which **amino acid residue** on the target protein is the C-terminus of ubiquitin typically attached via an isopeptide bond?

(A) Serine

(B) Threonine

(C) Cysteine

(D) Lysine

Q49. During meiosis, homologous chromosomes pair up in a process called **synapsis**, forming bivalents (tetrads) held together by the synaptonemal complex. In which stage of meiosis does synapsis occur?

(A) Metaphase I

(B) Prophase I (specifically during the zygotene sub-stage)

(C) Anaphase II

(D) Prophase II

Q50. At the **G1/S checkpoint**, the CDK4/6–cyclin D complex phosphorylates the retinoblastoma protein (Rb). What is the direct consequence of Rb phosphorylation?

(A) Release of the E2F transcription factor, allowing transcription of genes required for S-phase entry

(B) Degradation of cyclin E by the ubiquitin-proteasome pathway

(C) Activation of the spindle assembly checkpoint

(D) Inhibition of CDK2–cyclin E activity

Q51. The *lac* operon of *E. coli* is normally repressed by the Lac repressor protein. Which small-molecule **inducer** binds the Lac repressor and causes it to dissociate from the operator, allowing transcription of the *lacZYA* genes?

(A) Glucose

(B) cAMP (cyclic adenosine monophosphate)

(C) Allolactose (a metabolite of lactose)

(D) Galactose (a product of lactose hydrolysis)

Q52. In a large, randomly mating population at Hardy-Weinberg equilibrium, the frequency of homozygous recessive individuals (q^2) is 0.09. What is the frequency of **heterozygotes** ($2pq$) in this population?

(A) 0.30

(B) 0.21

(C) 0.49

(D) 0.42

Q53. A laboratory technician accidentally introduces a mutation that **shifts the reading frame** of an mRNA, causing all downstream codons to be read incorrectly. What type of mutation causes a frameshift?

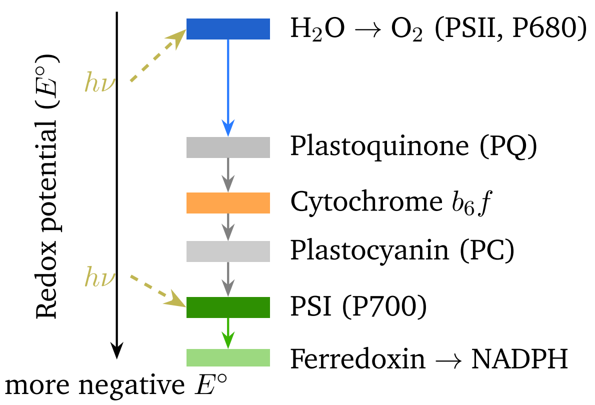
(A) Substitution of one nucleotide for another (missense or silent mutation)

(B) Insertion or deletion of a number of nucleotides that is *not* a multiple of three

(C) Inversion of a large chromosomal segment within the same chromosome

(D) Transition mutation converting a sense codon to a stop codon

Q54. The **Z-scheme** below depicts the light-driven electron transport chain in the thylakoid membrane during the light reactions of photosynthesis. Electrons flow from water through multiple carriers to ultimately reduce $NADP^+$ to NADPH.



Which component in the Z-scheme is directly responsible for **oxidising water** (oxygen-evolving complex)?

(A) Photosystem II (P680)

(B) Cytochrome b_6f complex

(C) Photosystem I (P700)

(D) $NADP^+$ reductase (ferredoxin-$NADP^+$ reductase, FNR)

Q55. In C4 plants (e.g. maize, sugarcane), CO_2 is first fixed in mesophyll cells into a **4-carbon compound** (oxaloacetate, OAA) before being transferred to bundle-sheath cells. Which enzyme catalyses this initial carboxylation step?

(A) RuBisCO (ribulose-1,5-bisphosphate carboxylase/oxygenase)

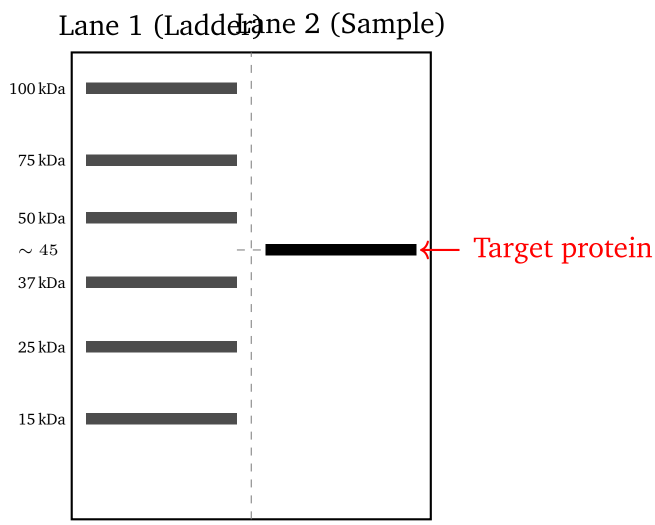
(B) Pyruvate kinase

(C) PEP carboxylase (phosphoenolpyruvate carboxylase)

(D) Malate dehydrogenase

BIOLOGY — Sub-section B (Q56–Q60: +2 marks each; no negative marking)

Q56. The schematic below shows a **Western blot** result. A cell lysate was separated by SDS-PAGE (molecular weight ladder in lane 1), transferred to a membrane, and probed with a specific antibody. A single dark band appears at approximately 45 kDa in the experimental lane.



What does the **molecular weight** (position) of the antibody-detected band in lane 2 indicate?

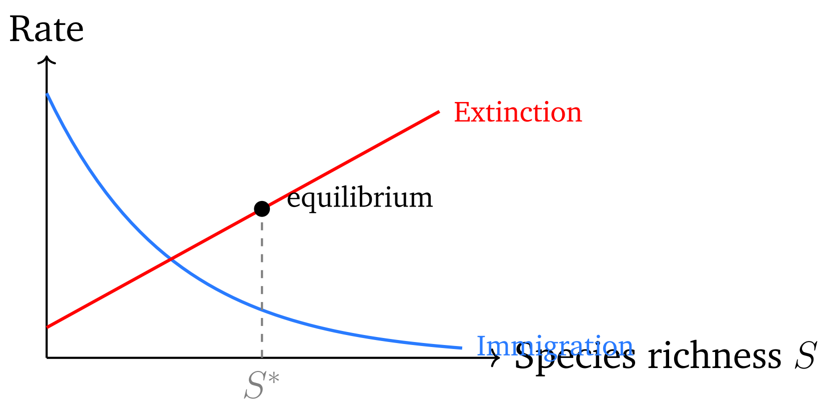
(A) The amount of mRNA transcribed from the gene encoding the target protein

- **(B)** The isoelectric point (pI) of the detected protein
- **(C)** The number of copies of the target protein present per cell
- **(D)** The approximate molecular weight (size) of the detected protein (∼45 kDa)

Q57. A testcross involving two genes on the same chromosome yields the following offspring: 44% parental class 1, 44% parental class 2, 6% recombinant class 1, 6% recombinant class 2. The total recombination frequency is **12%**. What does this indicate about the positions of the two genes?

- **(A)** The two genes are located approximately **12 centiMorgans (cM)** apart on the same chromosome
- **(B)** The two genes are on different chromosomes and assort independently (unlinked)
- **(C)** The two genes are 12 base pairs apart in the DNA sequence
- **(D)** The 12% recombination frequency indicates the genes are in repulsion (trans) configuration only

Q58. The **MacArthur-Wilson equilibrium model of island biogeography** predicts that species richness on an island is determined by two opposing processes: immigration from a mainland source and local extinction. The graph below shows immigration rate (decreasing) and extinction rate (increasing) as functions of species richness S.



What determines the **equilibrium species number** S^* on a given island?

(A) Only the immigration rate from the mainland source pool

(B) Only the local extinction rate on the island

(C) The balance between the immigration rate and the extinction rate (the point where the two curves intersect)

(D) The total land area of the mainland source habitat alone

Q59. Interferon-γ (IFN-γ) binds its receptor on the cell surface, leading to activation of receptor-associated **JAK1** and **JAK2** kinases. What do the activated JAKs then do to the STAT1 proteins to initiate downstream signalling?

(A) They polyubiquitinate STAT1, marking it for proteasomal degradation

(B) They phosphorylate STAT1 on a specific tyrosine residue, enabling STAT1 homodimerisation and nuclear translocation

(C) They cleave STAT1 proteolytically, releasing its DNA-binding domain

(D) They acetylate STAT1 on lysine residues, enhancing its transcriptional activity

Q60. The **classical complement pathway** is initiated when the complement protein C1q binds to antibody-antigen complexes on a target surface. Which **immunoglobulin classes (isotypes)** are capable of activating the classical complement pathway by binding C1q?

(A) IgA and IgE

(B) IgD and IgM

(C) IgA and IgG

(D) IgG and IgM

Detailed Solutions

Solution

Q1.

Concept — Simple Interest:

Simple interest is computed as $I = \dfrac{P \times R \times T}{100}$, and the total amount is $A = P + I$.

Step 1 — Calculate interest:

$I = \dfrac{5000 \times 8 \times 3}{100} = \dfrac{1{,}20{,}000}{100} = 1{,}200$

Step 2 — Total amount:

$A = 5{,}000 + 1{,}200 = \mathbf{6{,}200}$

Why other options are wrong:

- **(A) ₹5,400** uses only 1 year of interest ($5000 \times 0.08 = 400$, then $5000 + 400 = 5400$) — incorrect duration.
- **(B) ₹5,800** corresponds to 2 years of interest ($I = 800$) — one year short.
- **(D) ₹6,800** overstates; this would require $I = 1800$, i.e. $R \approx 12\%$ or $T = 4.5$ years.

Final Answer: $A = ₹\,6{,}200 \Rightarrow$ **(C)**

Answer: (C) ↑ Go back to Q 1

Solution

Q2.

Concept — Ratio and Proportion:

If $a : b = 3 : 7$, then $a = \frac{3}{3+7} \times (a + b) = \frac{3}{10} \times 50$.

Step 1 — Solve for a:

$a = \dfrac{3}{10} \times 50 = \mathbf{15}$

Verification: $b = 50 - 15 = 35$. Check ratio: $15 : 35 = 3 : 7$ ✓

Why other options are wrong:

- **(B)** 20 gives ratio $20 : 30 = 2 : 3$, not $3 : 7$.
- **(C)** 21 gives ratio $21 : 29$, not a simple ratio of 3:7.
- **(D)** 25 gives ratio $25 : 25 = 1 : 1$, not $3 : 7$.

Final Answer: $a = 15 \Rightarrow$ **(A)**

Answer: (A) ↑ Go back to Q 2

Solution

Concept — Speed, Distance, Time:

For a train to completely cross a platform, the total distance covered equals (length of train + length of platform).

Step 1 — Convert speed:
$72\,\text{km/h} = 72 \times \dfrac{1000}{3600} = 20\,\text{m/s}$

Step 2 — Total distance and time:
$d = 200 + 300 = 500\,\text{m}$
$t = \dfrac{d}{v} = \dfrac{500}{20} = \mathbf{25\,s}$

Why other options are wrong:

Q3.
- **(A)** 20 s corresponds to crossing only the platform length ($300/20 = 15\,\text{s}$ is still not 20 s) or misapplying the distance.
- **(C)** 30 s would require $d = 600\,\text{m}$ — $100\,\text{m}$ too long.
- **(D)** 35 s would require $d = 700\,\text{m}$ — corresponds to adding an extra train length.

Final Answer: $t = 25\,\text{s} \Rightarrow$ **(B)**

Answer: (B) ↑ Go back to Q 3

Solution

Concept — Inclusion-Exclusion Principle:
$n(A \cup B) = n(A) + n(B) - n(A \cap B)$

Step 1 — Substitute values:
$n(A \cup B) = 40 + 35 - 15 = \mathbf{60}$

Why other options are wrong:

Q4.
- **(A)** 75 $= 40 + 35$, forgetting to subtract the intersection (counts it twice).
- **(B)** 70 subtracts only 5 instead of 15.
- **(C)** 65 subtracts only 10 instead of 15.

Final Answer: $n(A \cup B) = 60 \Rightarrow$ **(D)**

Answer: (D) ↑ Go back to Q 4

Solution

Concept — Classical Probability:
A standard deck has 52 cards. Face cards are Jack, Queen, King — 3 per suit, 12 total. Red suits are hearts and diamonds (2 suits), so red face cards $= 2 \times 3 = 6$.

Step 1 — Probability:
$P = \dfrac{6}{52} = \dfrac{3}{26}$

Why other options are wrong:

Q5.
- **(A)** $\frac{1}{13} = \frac{4}{52}$: this would represent 4 cards (e.g. all Kings), not red face cards.
- **(B)** $\frac{1}{26} = \frac{2}{52}$: only 2 cards — not the correct count of red face cards.

- **(D)** $\frac{2}{13} = \frac{8}{52}$: 8 cards — over-counts by including non-face number cards.

Final Answer: $P = \dfrac{3}{26} \Rightarrow$ **(C)**

Answer: (C) ↑ Go back to Q 5

Solution

Concept — Geometric Series:
In a geometric sequence, each term is obtained by multiplying the previous term by a constant ratio r.

Step 1 — Find common ratio:
$$r = \frac{6}{2} = \frac{18}{6} = \frac{54}{18} = 3$$
Step 2 — Next term:
$54 \times 3 =$ **162**

Why other options are wrong:

Q6.

- **(B)** 108: this would be 54×2 — ratio of 2, not 3.
- **(C)** 216: this would be the 5th term if the sequence started at 1 $(1, 3, 9, 27, 81, 243 \ldots)$ — off by one position.
- **(D)** 144: no geometric rule with ratio 3 produces this value.

Final Answer: Next term $= 162 \Rightarrow$ **(A)**

Answer: (A) ↑ Go back to Q 6

Solution

Concept — Coding-Decoding (Letter Shift):
Each letter is replaced by the next letter in the English alphabet (A→B, B→C, . . . , Z→A).

Step 1 — Encode each letter of DOG:
D → E | O → P | G → H
Code: **EPH**

Verification with given example:
C→D, A→B, T→U ⇒ DBU ✓

Why other options are wrong:

Q7.

- **(A)** EPN: N is the code for M, not G; G shifts to H, not N.
- **(C)** DPH: the first letter D is not shifted; D should become E.
- **(D)** ENH: N is wrong for O; O shifts to P.

Final Answer: DOG → EPH ⇒ **(B)**

Answer: (B) ↑ Go back to Q 7

Q8.

Solution

Concept — Unit Conversion and Scientific Notation:
$1\,\mu g = 10^{-6}$ g (micro $= 10^{-6}$).

Step 1 — Convert:
$3.2\,\mu g = 3.2 \times 10^{-6}$ g

Why other options are wrong:

- **(A)** 3.2×10^{-3} g = 3.2 mg (milligrams) — wrong prefix; milli = 10^{-3}.
- **(B)** 3.2×10^{-4} g has no standard SI prefix for this exponent (10^{-4}).
- **(C)** 3.2×10^{-9} g = 3.2 ng (nanograms) — nano = 10^{-9}, three orders of magnitude too small.

Final Answer: $3.2\,\mu g = 3.2 \times 10^{-6}$ g $\Rightarrow$ **(D)**

Answer: (D) ↑ Go back to Q 8

Q9.

Solution

Concept — Biological Analogy (Organelle-Process Pairing):
The analogy maps a metabolic process to the organelle where it takes place. Photosynthesis (light reactions + Calvin cycle) occurs in the **chloroplast**. Aerobic cellular respiration (Krebs cycle, oxidative phosphorylation) occurs in the **mitochondria**.

Why other options are wrong:

- **(A)** Nucleus: site of transcription and DNA replication, not aerobic respiration.
- **(B)** Ribosome: site of translation (protein synthesis), not respiration.
- **(D)** Cell membrane: site of some signalling and transport; not the compartment for ATP synthesis via the electron transport chain.

Final Answer: Aerobic respiration $\leftrightarrow$ Mitochondria $\Rightarrow$ **(C)**

Answer: (C) ↑ Go back to Q 9

Solution

Concept — Day-of-the-Week Calculation:
Count the total number of days from Jan 1 to Mar 15 (not counting Jan 1 itself), then find the remainder mod 7.

Step 1 — Days elapsed after Jan 1, 2024:
January 2 – 31: 30 days
February 2024 (leap year, 29 days): 29 days

March 1 – 15: 15 days
Total: $30 + 29 + 15 = 74$ days

Step 2 — Day of the week:
$74 \div 7 = 10$ remainder 4 (since $10 \times 7 = 70$)
Monday $+4 =$ **Friday**

Why other options are wrong:

Q10.

- **(B)** Saturday requires remainder 5 ($74 \equiv 5$), but $74 = 10 \times 7 + 4$, not remainder 5.
- **(C)** Thursday requires remainder 3, not 4.
- **(D)** Sunday requires remainder 6, not 4.

Final Answer: March 15, 2024 is a **Friday** $\Rightarrow$ **(A)**

Answer: (A) ↑ Go back to Q 10

Solution

Concept — Radioactive Decay Law:
The equation $N = N_0\, e^{-\lambda t}$ describes exponential decay. Differentiating: $\frac{dN}{dt} = -\lambda N$, so $\lambda = -\frac{1}{N}\frac{dN}{dt}$. This shows λ is the *fractional rate of decay per nucleus per unit time*, i.e. the **decay constant.**

Step 1 — Physical meaning of λ:
λ sets the rate at which N decreases: larger $\lambda \Rightarrow$ faster decay (shorter half-life $t_{1/2} = \ln 2/\lambda$). The graph shows the steeper the initial slope, the larger λ.

Why other options are wrong:

Q11.

- **(A)** N_0 is the initial count at $t = 0$, a separate parameter (the pre-exponential intercept), not λ.
- **(C)** The half-life is $t_{1/2} = \ln 2/\lambda$; they are related but $\lambda \neq t_{1/2}$.
- **(D)** Complete decay is approached asymptotically ($N \to 0$ only as $t \to \infty$), not at a finite time.

Final Answer: λ is the decay constant (probability of decay per nucleus per unit time) $\Rightarrow$ **(B)**

Answer: (B) ↑ Go back to Q 11

Solution

Concept — Choosing the Correct Statistical Test:
Hair colour and eye colour are both **categorical** (nominal) variables. When asking whether two categorical variables are associated or independent in a contingency table, the appropriate test is the χ^2 **(chi-square) test of independence**.

Why other options are wrong:

Q12.
- **(A)** Student's t-test compares *means* of two groups with continuous/numerical data; not applicable to categorical variables.
- **(B)** Pearson's r measures linear correlation between two *continuous* variables; inapplicable here.
- **(C)** ANOVA compares *means* across three or more groups; requires a continuous outcome variable.

Final Answer: Chi-square (χ^2) test of independence $\Rightarrow$ **(D)**

Answer: (D) ↑ Go back to Q 12

Solution

Concept — Correct Interpretation of a Confidence Interval:
A 95% CI is a *frequentist* statement about the *procedure*, not about this specific interval. The parameter is fixed (unknown); the interval varies from sample to sample. Thus: in repeated sampling, 95% of intervals constructed this way would contain the true parameter.

Why other options are wrong:

Q13.
- **(A)** Assigning a 95% probability to this specific interval containing the true mean is the Bayesian credible-interval interpretation, not the classical CI.
- **(B)** The CI is about the population *mean*, not about individual data values; a prediction interval describes data values.
- **(D)** The sample mean is a deterministic calculation from the data; it is not probabilistic itself.

Final Answer: 95% of such intervals would contain the true parameter in repeated sampling $\Rightarrow$ **(C)**

Answer: (C) ↑ Go back to Q 13

Solution

Concept — Pearson Correlation Coefficient:
r ranges from -1 to $+1$. A value of $r = +0.92$ is close to $+1$, indicating a **strong positive linear** relationship: as one variable increases, the other tends to increase proportionally.

Why other options are wrong:

Q14.
- **(B)** A *weak* positive relationship corresponds to r close to 0 (e.g. $r \approx 0.2$); $r = 0.92$ is strong.
- **(C)** A *perfect* correlation is $r = 1.00$ (no scatter). Furthermore, correlation never implies causation.

- **(D)** $r = 0.92$ is highly significant for $n = 50$; calling it "insignificant" is incorrect.

Final Answer: Strong positive linear relationship $\Rightarrow$ **(A)**

Answer: (A) ↑ Go back to Q 14

Solution

Concept — Relationship Between Variance and Standard Deviation:
Standard deviation (σ) is the positive square root of variance (σ^2): $\sigma = \sqrt{\sigma^2}$.

Step 1 — Calculate:
$\sigma = \sqrt{25} = \mathbf{5}$

Why other options are wrong:

Q15.

- **(A)** 12.5 = variance/2; halving is not the correct relationship.
- **(C)** 625 = 25^2; squaring the variance gives the fourth central moment (kurtosis term), not SD.
- **(D)** 25 is the variance itself, not the standard deviation.

Final Answer: $\sigma = \sqrt{25} = 5 \Rightarrow$ **(B)**

Answer: (B) ↑ Go back to Q 15

Solution

Concept — Dynamics on an Inclined Plane with Friction:
Applying Newton's second law along the slope (taking down the slope as positive):

$$ma = mg\sin\theta - f_k = mg\sin\theta - \mu_k mg\cos\theta = mg(\sin\theta - \mu_k\cos\theta)$$

Step 1 — Substitute values:
$a = g(\sin 30 - \mu_k \cos 30) = 10\,(0.500 - 0.3 \times 0.866)$
$= 10\,(0.500 - 0.260) = 10 \times 0.240 = \mathbf{2.4\,m/s^2}$

Verification: Normal force $N = mg\cos 30 = 5 \times 10 \times 0.866 = 43.3\,\text{N}$; friction $f = 0.3 \times 43.3 = 13.0\,\text{N}$; net force $= mg\sin 30 - f = 25 - 13 = 12\,\text{N}$; $a = 12/5 = 2.4\,\text{m/s}^2$ ✓

Why other options are wrong:

Q16.

- **(A)** $1.2\,\text{m/s}^2$: uses $g = 5$ or incorrectly doubles friction.
- **(B)** $3.5\,\text{m/s}^2$: close to $g\sin 30 - \mu_k g \sin 30$ (wrong force component for friction).
- **(C)** $5.0\,\text{m/s}^2 = g\sin 30$ with no friction — neglects μ_k.

Final Answer: $a = 2.4\,\text{m/s}^2$ down the incline $\Rightarrow$ **(D)**

Answer: (D) ↑ Go back to Q 16

Solution

Concept — Projectile Range Formula:
$R = \frac{v_0^2 \sin 2\theta}{g}$. To maximise R, maximise $\sin 2\theta$. The sine function is maximum $(= 1)$ when its argument $= 90$, i.e. when $2\theta = 90$, so $\theta = 45$.

Why other options are wrong:

Q17.

- **(A)** $\theta = 30$: $\sin 60 \approx 0.866 < 1$; range is not maximum.
- **(B)** $\theta = 60$: $\sin 120 = \sin 60 \approx 0.866$ — same range as 30 (complementary angles), not maximum.
- **(D)** $\theta = 90$: $\sin 180 = 0$; no horizontal range (straight up).

Final Answer: Maximum range at $\theta = 45 \Rightarrow$ **(C)**

Answer: (C) ↑ Go back to Q 17

Solution

Concept — Conservation of Mechanical Energy:
With no air resistance, all potential energy converts to kinetic energy:

$$KE = mgh$$

Step 1 — Calculate:
$KE = 2\,\text{kg} \times 10\,\text{m/s}^2 \times 10\,\text{m} = \mathbf{200\,J}$

Verification via velocity:
$v = \sqrt{2gh} = \sqrt{200} \approx 14.1\,\text{m/s}$; $KE = \frac{1}{2}mv^2 = \frac{1}{2}(2)(200) = 200\,\text{J}$ ✓

Why other options are wrong:

Q18.

- **(B)** $100\,\text{J}$ uses $m = 1\,\text{kg}$ or $h = 5\,\text{m}$; neither matches the given data.
- **(C)** $400\,\text{J}$ doubles the answer erroneously (e.g. if g were doubled or $h = 20\,\text{m}$).
- **(D)** $20\,\text{J} = mgh$ with $g = 1$ — dimension error.

Final Answer: $KE = 200\,\text{J} \Rightarrow$ **(A)**

Answer: (A) ↑ Go back to Q 18

Solution

Concept — Bernoulli's Equation for Ideal Fluid Flow:
For steady, incompressible flow along a horizontal streamline:

$$P + \tfrac{1}{2}\rho v^2 = \text{constant}$$

When the pipe narrows (area decreases), continuity (Av = const) requires v to increase. If v increases, $\frac{1}{2}\rho v^2$ increases, so P must **decrease**.

Why other options are wrong:

Q19.

- **(A)** Pressure increases: this violates Bernoulli's equation; it is the common misconception ("more squeezing" $\Rightarrow$ more pressure).
- **(C)** Pressure unchanged: only true if velocity is unchanged, which contradicts the continuity equation.
- **(D)** Fluid density increase: for an incompressible fluid, density is constant by definition.

Final Answer: Pressure **decreases** in the constricted section $\Rightarrow$ **(B)**

Answer: (B) ↑ Go back to Q 19

Solution

Concept — Period of a Simple Pendulum:

$$T = 2\pi\sqrt{\frac{L}{g}}$$

Step 1 — Substitute:

$$T = 2\pi\sqrt{\frac{4}{10}} = 2\pi\sqrt{0.4} = 2\pi \times \frac{2}{\sqrt{10}}$$

Step 2 — Numerical evaluation:

Using $\pi^2 \approx 10$: $T^2 = 4\pi^2 \times \frac{4}{10} = \frac{16\pi^2}{10} \approx \frac{16 \times 10}{10} = 16$, so $T = \sqrt{16} = \mathbf{4.0\,s}$

Why other options are wrong:

Q20.

- **(A)** $2\pi \approx 6.28\,\text{s}$: this would need $L/g = 1$, i.e. $L = 10\,\text{m}$ for $g = 10\,\text{m/s}^2$.
- **(B)** $\pi \approx 3.14\,\text{s}$: this would need $T^2 = \pi^2$, giving $L = 2.5\,\text{m}$.
- **(C)** $2\,\text{s}$: this needs $L = 1\,\text{m}$ (since $T = 2\pi\sqrt{0.1} = 2\pi/\sqrt{10} \approx 2\,\text{s}$ for $L = 1\,\text{m}$).

Final Answer: $T = 4.0\,\text{s} \Rightarrow$ **(D)**

Answer: (D) ↑ Go back to Q 20

Solution

Concept — Image Formation by a Concave Mirror:

For a concave mirror: when the object is placed *between the focus F and the pole P* (i.e. within the focal length), the reflected rays diverge and appear to come from a point *behind* the mirror. The image is **virtual** (cannot be projected on a screen), **erect** (same orientation as the object), and **magnified** ($|m| > 1$).

Summary of concave mirror cases:

Object beyond C: real, inverted, diminished.
Object at C: real, inverted, same size.

Object between C and F: real, inverted, magnified.
Object *within* F: **virtual, erect, magnified.**

Why other options are wrong:

Q21.

- **(B)** Real, inverted, magnified describes the object placed between C and F.
- **(C)** Virtual, inverted, diminished: concave mirrors do not produce inverted virtual images.
- **(D)** Real, erect, same size: concave mirrors never form real erect images.

Final Answer: Virtual, erect, and magnified $\Rightarrow$ **(A)**

Answer: (A) ↑ Go back to Q 21

Solution

Concept — Capacitors in Series:
For capacitors in series, $\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2}$.

Step 1 — Substitute:
$$\frac{1}{C_{\text{eq}}} = \frac{1}{4} + \frac{1}{12} = \frac{3}{12} + \frac{1}{12} = \frac{4}{12} = \frac{1}{3}$$

Step 2 — Solve:
$C_{\text{eq}} = 3\,\mu\text{F}$

Shortcut: For two capacitors in series: $C_{\text{eq}} = \frac{C_1C_2}{C_1 + C_2} = \frac{4 \times 12}{4 + 12} = \frac{48}{16} = 3\,\mu\text{F}$ ✓

Why other options are wrong:

Q22.

- **(A)** $16\,\mu\text{F} = C_1 + C_2$: this is the formula for *parallel* capacitors, not series.
- **(B)** $48\,\mu\text{F} = C_1 \times C_2$: no physical formula produces this result.
- **(D)** $8\,\mu\text{F} = (C_1 + C_2)/2$: simple averaging has no physical basis here.

Final Answer: $C_{\text{eq}} = 3\,\mu\text{F} \Rightarrow$ **(C)**

Answer: (C) ↑ Go back to Q 22

Solution

Concept — Resistance and Wire Geometry:
$R = \frac{\rho L}{A} = \frac{\rho L}{\pi r^2}$. If length $L \to 2L$ and radius $r \to r/2$:

Step 1 — New resistance:
$$R' = \frac{\rho(2L)}{\pi(r/2)^2} = \frac{2\rho L}{\pi r^2/4} = \frac{8\rho L}{\pi r^2} = 8R$$

Breakdown of each factor:
Doubling length doubles R: factor of 2.
Halving radius reduces area by 4 (since $A \propto r^2$), increasing R by 4.

Combined: $2 \times 4 = \mathbf{8}$.

Why other options are wrong:

Q23.

- **(A)** Factor 2: only accounts for the length change; ignores the area change from halving the radius.
- **(C)** Factor 4: only accounts for the area change; ignores the length doubling.
- **(D)** Factor 16: over-counts; would result from halving the radius twice ($r \to r/4$).

Final Answer: Resistance increases by a factor of $8 \Rightarrow$ **(B)**

Answer: (B) ↑ Go back to Q 23

Solution

Concept — Photoelectric Effect: Threshold Wavelength:
$\lambda_0 = \frac{hc}{\phi}$. Using the convenient product $hc = 1{,}240\,\text{eV nm}$:

Step 1 — Substitute:
$$\lambda_0 = \frac{1{,}240\,\text{eV nm}}{2\,\text{eV}} = 620\,\text{nm}$$
This lies in the orange-red visible region ($\approx 620\,\text{nm}$).

Why other options are wrong:

Q24.

- **(A)** 248 nm: corresponds to $\phi = 1240/248 = 5\,\text{eV}$ — much larger work function.
- **(B)** 414 nm: corresponds to $\phi \approx 3\,\text{eV}$ — $1.5\times$ too large.
- **(C)** 496 nm: corresponds to $\phi = 1240/496 = 2.5\,\text{eV}$ — not 2 eV.

Final Answer: $\lambda_0 = 620\,\text{nm} \Rightarrow$ **(D)**

Answer: (D) ↑ Go back to Q 24

Solution

Concept — Rutherford's Alpha-Scattering Experiment:
Rutherford observed that ∼99.98% of α-particles passed straight through the gold foil with negligible deflection. This can only be explained if most of the atom is **empty space** — the atom is not a "plum-pudding" of uniform charge but has a tiny, dense, positively charged nucleus.

Why other options are wrong:

Q25.

- **(B)** Uniform positive charge is the Thomson "plum-pudding" model, which Rutherford's experiment disproved; a diffuse positive charge would scatter α-particles only weakly and uniformly.
- **(C)** A diffuse electron cloud is part of the Bohr/quantum model; electrons

are too light to significantly deflect heavy α-particles.

- **(D)** Neutrons were discovered later by Chadwick (1932); Rutherford's experiment does not directly reveal the neutron content.

Final Answer: Most of the atom is **empty space** $\Rightarrow$ **(A)**

Answer: (A) ↑ Go back to Q 25

Solution

Concept — Carnot Efficiency:
The Carnot efficiency gives the *maximum possible* efficiency for a heat engine operating between two thermal reservoirs:

$$\eta = 1 - \frac{T_C}{T_H}$$

where temperatures must be in Kelvin.

Step 1 — Substitute:
$\eta = 1 - \frac{300}{800} = 1 - 0.375 = 0.625 = \mathbf{62.5\%}$

Verification: Work extracted per joule of heat input = 62.5 J; heat rejected to cold reservoir = 37.5 J. Energy conservation: $62.5 + 37.5 = 100\,\text{J}$ ✓

Why other options are wrong:

Q26.

- **(A)** 37.5% = T_C/T_H (the fraction of heat rejected, not efficiency).
- **(B)** 50%: would require $T_C = T_H/2 = 400\,\text{K}$, not 300 K.
- **(D)** 75%: would require $T_C = 200\,\text{K}$.

Final Answer: $\eta = 62.5\% \Rightarrow$ **(C)**

Answer: (C) ↑ Go back to Q 26

Solution

Concept — Doppler Effect (Moving Source):
When a source moves *toward* a stationary observer, the observed frequency is:

$$f_{\text{obs}} = f_s \cdot \frac{v}{v - v_s}$$

Step 1 — Substitute $v_s = v/2$:
$f_{\text{obs}} = f_s \cdot \frac{v}{v - v/2} = f_s \cdot \frac{v}{v/2} = f_s \cdot 2$

Step 2 — Ratio:
$\frac{f_{\text{obs}}}{f_s} = \mathbf{2}$

Physical interpretation: The source compresses the wavefronts in front of it; the observer hears twice the emitted frequency.

Why other options are wrong:

Q27.

- **(B)** 1.5: would result from $v_s = v/3$ ($f = v/(v - v/3) = 3/2 = 1.5$).
- **(C)** 3: would result from $v_s = 2v/3$.
- **(D)** 4: would result from $v_s = 3v/4$.

Final Answer: $f_{\text{obs}}/f_s = 2 \Rightarrow$ **(A)**

Answer: (A) ↑ Go back to Q 27

Solution

Concept — Young's Double-Slit Fringe Width:
The fringe width (spacing between adjacent bright fringes) is:

$$\beta = \frac{\lambda D}{d}$$

Step 1 — Convert units and substitute:
$\lambda = 600\,\text{nm} = 600 \times 10^{-9}\,\text{m}$, $D = 1\,\text{m}$, $d = 0.5\,\text{mm} = 5 \times 10^{-4}\,\text{m}$:

$$\beta = \frac{600 \times 10^{-9} \times 1}{5 \times 10^{-4}} = \frac{6 \times 10^{-7}}{5 \times 10^{-4}} = 1.2 \times 10^{-3}\,\text{m} = \mathbf{1.2\,mm}$$

Why other options are wrong:

Q28.

- **(A)** 0.6 mm: half the correct answer; arises from using $d = 1\,\text{mm}$ (doubling slit separation).
- **(C)** 2.4 mm: double the correct answer; arises from using $d = 0.25\,\text{mm}$.
- **(D)** 0.3 mm: quarter of the correct value; arises from using $d = 2\,\text{mm}$.

Final Answer: $\beta = 1.2\,\text{mm} \Rightarrow$ **(B)**

Answer: (B) ↑ Go back to Q 28

Solution

Concept — RC Circuit Time Constant:
The time constant $\tau = RC$ represents the time for the capacitor voltage to reach $(1 - e^{-1}) \approx 63.2\%$ of its final value.

Step 1 — Convert to SI base units and multiply:
$R = 100\,\text{k}\Omega = 10^5\,\Omega$, $C = 10\,\mu\text{F} = 10^{-5}\,\text{F}$:

$$\tau = RC = 10^5\,\Omega \times 10^{-5}\,\text{F} = \mathbf{1\,s}$$

Why other options are wrong:

Q29.

- **(A)** $0.1\,\text{s}$: off by a factor of 10; would require $C = 1\,\mu\text{F}$ or $R = 10\,\text{k}\Omega$.
- **(B)** $0.5\,\text{s}$: half the correct value; no combination of given values yields this.
- **(C)** $2\,\text{s}$: double the correct value; would require $R = 200\,\text{k}\Omega$ or $C = 20\,\mu\text{F}$.

Final Answer: $\tau = 1\,\text{s} \Rightarrow$ **(D)**

Answer: (D) ↑ Go back to Q 29

Solution

Concept — Heisenberg Uncertainty Principle:
$\Delta x\,\Delta p \geq \frac{\hbar}{2}$. The minimum momentum uncertainty is:

$$\Delta p_{\text{min}} = \frac{\hbar}{2\,\Delta x}$$

Step 1 — Substitute values:
$\Delta x = 0.1\,\text{nm} = 10^{-10}\,\text{m}$, $\hbar = 1.05 \times 10^{-34}\,\text{J s}$:

$$\Delta p_{\text{min}} = \frac{1.05 \times 10^{-34}}{2 \times 10^{-10}} = \frac{1.05 \times 10^{-34}}{2 \times 10^{-10}} = 5.25 \times 10^{-25}\,\text{kg m/s}$$

Why other options are wrong:

Q30.

- **(A)** 1.05×10^{-24}: uses $\Delta p = \hbar/\Delta x$ (missing the factor of 2 in the denominator).
- **(C)** 2.10×10^{-24}: uses $\Delta p = 2\hbar/\Delta x$ (inverted the factor of 2).
- **(D)** 1.05×10^{-25}: off by a factor of 5; arithmetic error.

Final Answer: $\Delta p_{\text{min}} = 5.25 \times 10^{-25}\,\text{kg m/s} \Rightarrow$ **(B)**

Answer: (B) ↑ Go back to Q 30

Solution

Concept — Zaitsev's Rule (Dehydration of Alcohols):
Zaitsev's rule states that in elimination reactions, the major product is the **more substituted** alkene (more stable, lower energy). In 2-butanol ($CH_3-\underset{OH}{CH}-CH_2-CH_3$), elimination can occur toward C-1 (giving but-1-ene) or toward C-3 (giving but-2-ene). But-2-ene has the double bond flanked by two alkyl groups (disubstituted) and is therefore more stable.

Mechanism: Protonation of OH $\rightarrow$ carbocation at C-2 $\rightarrow$ loss of proton from C-1 or C-3 gives but-1-ene or but-2-ene respectively. The more substituted but-2-ene predominates.

Why other options are wrong:

Q31.

- **(B)** But-1-ene is the *minor* (Hofmann) product; less substituted, less stable.
- **(C)** Buta-1,3-diene requires a second elimination; does not occur readily under simple acid dehydration conditions.
- **(D)** Cyclobutane would require intramolecular C–C bond formation, not a simple elimination product.

Final Answer: Major product = but-2-ene (Zaitsev product) $\Rightarrow$ **(A)**

Answer: (A) ↑ Go back to Q 31

Solution

Concept — E2 Elimination Mechanism:
E2 (bimolecular elimination) is a one-step concerted mechanism requiring: (1) a **strong base** to abstract the β-H simultaneously; (2) an **anti-periplanar** geometry (≈ 180 dihedral angle between the β-H and the leaving group) for optimal orbital overlap; (3) the reaction is second-order overall (first order in substrate, first order in base).

Why other options are wrong:

Q32.

- **(A)** A *weak* base and syn-periplanar arrangement describe E1cb or an *Ei* (syn) elimination, not E2.
- **(B)** "Strong nucleophile" describes a substitution (S_N2) preference; gauche conformation cannot achieve anti-periplanar geometry needed for E2.
- **(D)** Acid catalyst with a carbocation intermediate describes an E1 mechanism.

Final Answer: Strong base + anti-periplanar arrangement $\Rightarrow$ **(C)**

Answer: (C) ↑ Go back to Q 32

Solution

Concept — VSEPR Theory for PCl_5:
Phosphorus in PCl_5 has 5 bonding pairs (BP) and 0 lone pairs (LP). VSEPR: 5 electron pairs arrange to minimise repulsion $\Rightarrow$ **trigonal bipyramidal** geometry. Hybridisation: sp^3d.

Bond angles: Equatorial P–Cl bonds at 120 to each other; axial P–Cl bonds at 90 to equatorial bonds.

Why other options are wrong:

Q33.

- **(A)** Tetrahedral (sp^3) has 4 electron pairs; PCl_5 has 5 pairs.
- **(B)** Octahedral (sp^3d^2) has 6 electron pairs; PCl_5 has only 5.
- **(C)** Square planar (dsp^2) has 4 bonding pairs with 2 lone pairs; PCl_5 has no

lone pairs on P.

Final Answer: Trigonal bipyramidal (sp^3d) $\Rightarrow$ **(D)**

Answer: (D) ↑ Go back to Q 33

Solution

Q34.

Concept — Born-Haber Cycle for NaCl:

The Born-Haber cycle decomposes the formation of an ionic solid into a series of steps. Of the major steps:

- Sublimation of Na(s): endothermic ($+107$ kJ/mol)
- Ionisation of Na(g): endothermic ($+496$ kJ/mol)
- Dissociation of Cl_2: endothermic ($+121$ kJ/mol per Cl)
- **Electron affinity of Cl: exothermic** (-349 kJ/mol) — Cl gains an electron and releases energy
- Lattice energy: exothermic (-787 kJ/mol)

Why other options are wrong:

- **(A)** Sublimation of Na(s) requires energy to overcome metallic bonding — endothermic.
- **(C)** Ionisation energy of Na requires energy to remove an electron — always endothermic.
- **(D)** Bond dissociation of Cl_2 requires energy to break the Cl–Cl bond — endothermic.

Final Answer: Electron affinity of chlorine is exothermic $\Rightarrow$ **(B)**

Answer: (B) ↑ Go back to Q 34

Solution

Concept — pH of a Weak Acid:

For a weak acid HA with concentration C and acid dissociation constant K_a, assuming $[H^+] = \sqrt{K_a C}$:

$$\text{pH} = \tfrac{1}{2}(\text{p}K_a + \text{p}C)$$

Step 1 — Calculate pK_a and pC:

$\text{p}K_a = -\log(1.8 \times 10^{-5}) = -\log 1.8 + 5 \approx 4.74$

$\text{p}C = -\log(0.1) = 1.00$

Step 2 — pH:

$\text{pH} = \tfrac{1}{2}(4.74 + 1.00) = \tfrac{1}{2}(5.74) = \mathbf{2.87}$

Verification: $[H^+] = \sqrt{1.8 \times 10^{-5} \times 0.1} = \sqrt{1.8 \times 10^{-6}} = 1.34 \times 10^{-3}$; $\text{pH} = -\log(1.34 \times 10^{-3}) \approx 2.87$ ✓

Why other options are wrong:

Q35.

- **(B)** 4.74 = pK_a; this is the pH at the half-equivalence point in a titration, not of the original solution.
- **(C)** 3.37 = $\frac{1}{2}(4.74 + 2.00)$: uses $pC = -\log(0.01) = 2$ instead of 1.
- **(D)** 1.00: this would be the pH of a *strong* acid at 0.1 M ($[H^+] = 0.1\,M$).

Final Answer: $\text{pH} = 2.87 \Rightarrow$ **(A)**

Answer: (A) ↑ Go back to Q 35

Solution

Concept — First Ionisation Energy Trend in Period 2:
The general trend across Period 2 is increasing IE_1 (Li < Be < B < C < N < O < F < Ne). However, there are two notable *exceptions*: B < Be (B has a $2p^1$ electron, easier to remove than Be's filled $2s^2$), and **O < N**.

Nitrogen has a half-filled $2p^3$ configuration (extra stability from exchange energy); oxygen's $2p^4$ has one paired electron in a $2p$ orbital, and that paired electron experiences **inter-electron repulsion**, making it easier to remove. Hence O has *lower* IE_1 than N.

Why other options are wrong:

Q36.

- **(A)** Li has the lowest IE in Period 2; it does not break any trend (it simply starts the period).
- **(B)** B also breaks the trend (B < Be due to $2p$ vs. $2s$), but the question specifies the element that has a paired $2p$ electron causing extra repulsion — that is O, not B.
- **(D)** Ne has the highest IE in Period 2; it follows the trend perfectly.

Final Answer: Oxygen (O) — lower IE than nitrogen due to paired $2p$ electron ⇒ **(C)**

Answer: (C) ↑ Go back to Q 36

Solution

Concept — Hybridisation of Carbon in CO_2:
In CO_2, carbon forms **two double bonds** (one with each oxygen): O=C=O. Each double bond consists of one σ bond and one π bond. The two σ bonds involve sp hybridised orbitals. With only two electron groups around carbon, VSEPR gives a **linear** geometry (bond angle 180).

Hybridisation: sp (one s + one p orbital hybridise; two unhybridised p orbitals form the two π bonds).

Why other options are wrong:

Q37.

- **(A)** sp^3: tetrahedral, ≈ 109.5; requires 4 electron groups (e.g. CH_4).
- **(B)** sp^3d: trigonal bipyramidal; requires 5 groups (e.g. PCl_5).
- **(C)** sp^2: trigonal planar with 120 bonds; requires 3 groups (e.g. BF_3, ethylene).

Final Answer: sp hybridisation; linear geometry $\Rightarrow$ **(D)**

Answer: (D) ↑ Go back to Q 37

Solution

Concept — Fischer Esterification:
Fischer esterification is the acid-catalysed condensation of a carboxylic acid with an alcohol to give an ester and water:

$$\mathrm{CH_3COOH + C_2H_5OH \underset{\Delta}{\overset{H_2SO_4}{\rightleftharpoons}} CH_3COOC_2H_5 + H_2O}$$

The reaction requires an **acid catalyst** (typically concentrated H_2SO_4 or HCl) and **heat**. It is reversible; excess alcohol or removal of water drives it forward.

Why other options are wrong:

Q38.

- **(A)** Aqueous NaOH (base) causes saponification of esters (the *reverse* reaction), not esterification of carboxylic acids.
- **(C)** Anhydrous HCl gas is used in some acid chloride preparations, not standard Fischer esterification with a carboxylic acid.
- **(D)** $AlCl_3$ is the Friedel–Crafts acylation catalyst; it operates on aromatic rings, not on aliphatic alcohols under Fischer conditions.

Final Answer: Conc. H_2SO_4, heat (reflux) $\Rightarrow$ **(B)**

Answer: (B) ↑ Go back to Q 38

Solution

Concept — Fischer Open-Chain Structure of Glucose:
D-Glucose is an aldohexose: a six-carbon monosaccharide with an **aldehyde** (−CHO) group at carbon 1. This is what classifies it as an "aldo" sugar. The free aldehyde is also responsible for glucose's reducing properties (it can be oxidised to gluconic acid), which is why glucose is a **reducing sugar**.

Carbon numbering: C-1 (−CHO) $\rightarrow$ C-2 (OH) $\rightarrow$ C-3 (OH) $\rightarrow$ C-4 (OH) $\rightarrow$ C-5 (OH) $\rightarrow$ C-6 ($-CH_2OH$).

Why other options are wrong:

Q39.
- **(B)** A ketone at C-2 describes *fructose* (a ketohexose); glucose is not a ketose.
- **(C)** A carboxylic acid at C-1 would make it gluconic acid (the oxidised product), not glucose itself.
- **(D)** $-CH_2OH$ is present at C-6 of glucose, not at C-1.

Final Answer: Aldehyde ($-CHO$) at carbon-1 $\Rightarrow$ **(A)**

Answer: (A) ↑ Go back to Q 39

Solution

Concept — Grignard Addition to a Ketone:
A Grignard reagent (RMgX) acts as a carbanion (R^-) and adds to the carbonyl carbon. Propanone (CH_3COCH_3) is a *ketone*; its carbonyl is attached to **two** alkyl groups. Adding CH_3MgBr gives an alkoxide that, after aqueous work-up, yields:

$$CH_3-\underset{OH}{\overset{CH3}{C}}-CH_3 = \text{2-methylpropan-2-ol } (tert\text{-butanol})$$

The product carbon bears **three** alkyl substituents (+ OH) $\Rightarrow$ **tertiary alcohol.**

Rule: Grignard + aldehyde $\to$ secondary alcohol; Grignard + ketone $\to$ tertiary alcohol; Grignard + formaldehyde $\to$ primary alcohol.

Why other options are wrong:

Q40.
- **(A)** Primary alcohol: results from Grignard addition to formaldehyde (HCHO), not a ketone.
- **(B)** Secondary alcohol: results from Grignard addition to an aldehyde (not a ketone).
- **(C)** Phenol: not produced by Grignard reactions on ketones under these conditions.

Final Answer: Tertiary alcohol (2-methylpropan-2-ol) $\Rightarrow$ **(D)**

Answer: (D) ↑ Go back to Q 40

Solution

Concept — ^{1}H NMR Integration:
In ^{1}H NMR, the area (integration) of each signal is directly proportional to the number of equivalent protons generating that signal. For ethanol (CH_3CH_2OH):

Q41.
- CH_3 group: **3 equivalent protons** $\to$ *largest* integration
- CH_2 group: 2 equivalent protons
- OH: 1 proton $\to$ smallest integration

Splitting patterns: CH_3 is split by 2 adjacent CH_2 protons $\to$ triplet; CH_2 is split by

3 adjacent CH_3 protons → quartet; OH is typically a broad singlet (fast exchange broadens it).

Why other options are wrong:

- **(A)** OH singlet (1H): smallest integration; only 1 proton.
- **(C)** CH_2 quartet (2H): intermediate integration; 2 protons, less than CH_3.
- **(D)** Equal integration of CH_3 and CH_2 is impossible; they have 3H and 2H respectively.

Final Answer: CH_3 triplet (3 protons, largest area) ⇒ **(B)**

Answer: (B) ↑ Go back to Q 41

Q42.

Solution

Concept — Bond Dissociation Energy and Bond Order:
Bond dissociation energy (BDE) measures how much energy is required to break a bond homolytically. Generally: single bonds < double bonds < triple bonds, and BDE increases with bond order. Among the bonds listed:

Bond	BDE (kJ/mol)
C–C	347 **(lowest)**
C–H	413
C=C	614
N≡N	945

Why other options are wrong:

- **(B)** C=C (614 kJ/mol): higher than C–C; double bond requires more energy.
- **(C)** N≡N (945 kJ/mol): the strongest bond among those listed (triple bond in dinitrogen).
- **(D)** C–H (413 kJ/mol): single bond but stronger than C–C due to smaller atomic radius of H.

Final Answer: C–C single bond (347 kJ/mol) requires least energy ⇒ **(A)**

Answer: (A) ↑ Go back to Q 42

Solution

Concept — Entropy Change on Dissolution:
When NaCl dissolves in water, the highly ordered crystal lattice disperses into Na^+ and Cl^- ions that are distributed randomly throughout the solution. The number of accessible microstates increases dramatically ⇒ $\Delta S_{\text{system}} > 0$.

Thermodynamic context: $\Delta G = \Delta H - T\Delta S$. NaCl dissolution is slightly endothermic ($\Delta H > 0$) but proceeds spontaneously at room temperature because

$T\Delta S > \Delta H$ (entropy drives the process).

Why other options are wrong:

Q43.

- **(A)** Incorrectly states that the crystal is *more disordered* than the solution; the crystal is an ordered lattice, so dissolution always *increases* disorder.
- **(B)** $\Delta S = 0$ would imply no change in disorder, which contradicts the physical process of crystalline order breaking down.
- **(D)** ΔS for dissolution depends on both lattice energy *and* hydration entropy; the statement is incomplete and incorrect.

Final Answer: $\Delta S > 0$ (positive entropy change) $\Rightarrow$ **(C)**

Answer: (C) ↑ Go back to Q 43

Solution

Concept — Nernst Equation and Effect of Q:

$$E = E^\circ - \frac{RT}{nF}\ln Q$$

When $Q > 1$, $\ln Q > 0$, so $\frac{RT}{nF}\ln Q > 0$. Subtracting a positive quantity from E° gives $E < E^\circ$.

Physical interpretation: $Q > 1$ means products are in excess; the reaction has a thermodynamic tendency to go backward, reducing the driving force for the forward (spontaneous) reaction, hence cell potential decreases below E°.

Why other options are wrong:

Q44.

- **(A)** $E > E^\circ$: true only when $Q < 1$ (reactants in excess, extra driving force).
- **(B)** $E = E^\circ$: only at standard conditions where $Q = 1$ (all activities = 1).
- **(C)** E depends on *both* temperature and Q; temperature appears in the Nernst factor RT/nF.

Final Answer: $E < E^\circ$ when $Q > 1 \Rightarrow$ **(D)**

Answer: (D) ↑ Go back to Q 44

Solution

Concept — Michaelis Constant K_m and Enzyme-Substrate Affinity:
$K_m = [S]$ when $v = V_{\max}/2$. A **low** K_m means the enzyme reaches half-maximal velocity at a *low* substrate concentration $\Rightarrow$ the enzyme has a **high affinity** for its substrate (tight binding; smaller dissociation constant $K_d \approx K_m$ for fast-equilibrium cases).

Why other options are wrong:

Q45.
- **(A)** Requiring a *high* substrate concentration to reach $V_{\max}/2$ describes a *high* K_m (low affinity) enzyme.
- **(C)** $V_{\max}$ is determined by k_{cat} and total enzyme concentration $[E]_T$; it is independent of K_m.
- **(D)** Competitive inhibitors increase the *apparent* K_m at physiological substrate concentrations; a low intrinsic K_m actually offers some protection against competitive inhibitors.

Final Answer: Low $K_m \Rightarrow$ high enzyme-substrate affinity $\Rightarrow$ **(B)**

Answer: (B) ↑ Go back to Q 45

Solution

Concept — B-DNA Structural Parameters:
B-DNA (Watson-Crick right-handed helix) has the following parameters under physiological conditions:

Q46.
- **Rise per base pair (axial rise):** $3.4\,\text{Å} = 0.34\,\text{nm}$
- Base pairs per turn: 10 (10.5 in solution)
- Pitch per full turn: $3.4\,\text{nm}$ (10 bp $\times$ 0.34 nm/bp)
- Diameter: $\approx 2\,\text{nm}$

Why other options are wrong:

- **(B)** 0.20 nm is too small; this does not correspond to any standard B-DNA measurement.
- **(C)** 0.54 nm is the rise per residue in an α-helix of protein, not DNA.
- **(D)** 3.4 nm is the *rise per complete turn* (pitch), not per individual base pair.

Final Answer: Rise per base pair = $0.34\,\text{nm} \Rightarrow$ **(A)**

Answer: (A) ↑ Go back to Q 46

Solution

Concept — Ribosome Subunit Functions in *E. coli*:
The 70S ribosome has two subunits with distinct roles:

Q47.
- **30S (small) subunit**: contains 16S rRNA + ∼21 proteins. Primary role: **mRNA decoding** — the A site within the 30S subunit base-pairs tRNA anticodon with the mRNA codon, ensuring translational fidelity.
- **50S (large) subunit**: contains 23S rRNA + 5S rRNA + ∼31 proteins. Primary role: **peptidyl transferase** activity (catalysed by 23S rRNA, a ribozyme) and houses the peptide exit tunnel.

Why other options are wrong:

- **(A)** Peptidyl transferase activity resides in the 50S (23S rRNA), not the 30S.
- **(B)** The 5S rRNA and peptide exit tunnel are features of the 50S subunit.
- **(D)** GTPase activity for translocation is provided by EF-G (a translation elongation factor), not by the ribosome subunit itself.

Final Answer: 30S subunit decodes mRNA (codon–anticodon recognition) ⇒ **(C)**

Answer: (C) ↑ Go back to Q 47

Q48.

Solution

Concept — Ubiquitin Attachment in the Ubiquitin-Proteasome Pathway:
Ubiquitin is a small 76-amino-acid protein. The E3 ubiquitin ligase catalyses the formation of an **isopeptide bond** between the C-terminal glycine (Gly-76) of ubiquitin and the ε-amino group of a **lysine** residue on the target protein. Polyubiquitin chains (typically linked via Lys-48 of ubiquitin itself) signal proteasomal degradation.

Why other options are wrong:

- **(A)** Serine: ubiquitin is not attached to serine; serine is the site of phosphorylation (kinases) or O-linked glycosylation.
- **(B)** Threonine: also a phosphorylation/glycosylation target, not ubiquitination.
- **(C)** Cysteine: forms disulfide bonds or coordinates metal ions; some ubiquitin-like modifiers (e.g. UFM1) have different linkages, but canonical ubiquitination targets lysine.

Final Answer: Ubiquitin attaches via isopeptide bond to **lysine** residues ⇒ **(D)**

Answer: (D) ↑ Go back to Q 48

Q49.

Solution

Concept — Stages of Meiosis and Synapsis:
Prophase I of meiosis is the longest and most complex stage, subdivided into five sub-stages: Leptotene, **Zygotene**, Pachytene, Diplotene, and Diakinesis.

- **Zygotene**: homologous chromosomes begin to synapse (pair), held together by the synaptonemal complex (SC).
- **Pachytene**: synapsis is complete; crossing over (recombination) occurs.

Why other options are wrong:

- **(A)** Metaphase I: bivalents are already formed and aligned at the metaphase plate; synapsis is completed long before.

- **(C)** Anaphase II: homologues have already separated; this stage involves separation of sister chromatids.
- **(D)** Prophase II: occurs in meiosis II after homologues have separated; no synapsis here.

Final Answer: Synapsis occurs in **Prophase I** (zygotene sub-stage) $\Rightarrow$ **(B)**

Answer: (B) ↑ Go back to Q 49

Q50.

Solution

Concept — G1/S Checkpoint and Rb Phosphorylation:
In early G1, hypophosphorylated (active) Rb binds and sequesters the transcription factor **E2F**, preventing transcription of S-phase genes. CDK4/6–cyclin D complex phosphorylates Rb, causing a conformational change that releases E2F. Free E2F then activates genes encoding cyclin E, DNA polymerase, and other S-phase proteins, committing the cell to divide.

Why other options are wrong:

- **(B)** Cyclin E degradation: Rb phosphorylation *promotes* cyclin E expression (via E2F), not its degradation; cyclin E is later degraded by SCF ubiquitin ligase.
- **(C)** Spindle assembly checkpoint: this checkpoint monitors kinetochore attachment in M phase; it is independent of Rb/E2F signalling.
- **(D)** CDK2 inhibition: phospho-Rb releases E2F, which then *activates* cyclin E transcription; cyclin E–CDK2 complexes are *activated*, not inhibited.

Final Answer: Rb phosphorylation releases E2F, allowing S-phase entry $\Rightarrow$ **(A)**

Answer: (A) ↑ Go back to Q 50

Q51.

Solution

Concept — *lac* Operon Regulation:
The Lac repressor is a tetrameric protein encoded by *lacI*. When lactose is present, it is converted by β-galactosidase to **allolactose** (1-6 linkage glucose-galactose). Allolactose binds the allosteric site of the Lac repressor, causing a conformational change that *prevents* it from binding the *lac* operator. With the operator free, RNA polymerase transcribes *lacZ*, *lacY*, and *lacA*.

Why other options are wrong:

- **(A)** Glucose: high glucose levels suppress the *lac* operon by catabolite repression (lowering cAMP); it is not the inducer.
- **(B)** cAMP: high cAMP (when glucose is absent) activates the catabolite activator protein (CAP), enhancing transcription but it does not itself inactivate

the Lac repressor.

- **(D)** Galactose: a product of lactose hydrolysis, but not the physiological inducer; allolactose (not galactose) inactivates the repressor.

Final Answer: Allolactose is the natural inducer of the *lac* operon $\Rightarrow$ **(C)**

Answer: (C) ↑ Go back to Q 51

Solution

Concept — Hardy-Weinberg Equilibrium:
If allele frequencies are p (dominant) and q (recessive) with $p + q = 1$, then genotype frequencies are p^2 (AA), $2pq$ (Aa), q^2 (aa).

Step 1 — Find q from q^2:
$q^2 = 0.09 \Rightarrow q = \sqrt{0.09} = 0.30$

Step 2 — Find p:
$p = 1 - q = 1 - 0.30 = 0.70$

Step 3 — Heterozygote frequency:
$2pq = 2 \times 0.70 \times 0.30 = 0.42$

Verification: $p^2 + 2pq + q^2 = 0.49 + 0.42 + 0.09 = 1.00$ ✓

Why other options are wrong:

Q52.

- **(A)** 0.30 $= q$ (recessive allele frequency), not the heterozygote frequency.
- **(B)** 0.21 $= pq$ (product of allele frequencies), missing the factor of 2.
- **(C)** 0.49 $= p^2$ (homozygous dominant frequency).

Final Answer: Heterozygote frequency $= 2pq = 0.42 \Rightarrow$ **(D)**

Answer: (D) ↑ Go back to Q 52

Solution

Concept — Frameshift Mutation:
The genetic code is read in **non-overlapping triplets (codons)** from a fixed start point. If nucleotides are inserted or deleted in a number that is *not* a multiple of three, the reading frame shifts, altering all codons downstream of the mutation. This typically produces a non-functional truncated or aberrant protein, and often introduces a premature stop codon.

Example: Original: `ATG CAT GCT ACG`. Insert one nucleotide (e.g. `T` after position 3): `ATG TCA TGC TAC G` $\rightarrow$ all subsequent codons are altered.

Why other options are wrong:

Q53.

- **(A)** Nucleotide substitution (missense/silent) changes one codon but does not shift the reading frame.

- **(C)** Chromosomal inversion affects gene order and may disrupt regulatory sequences, but codons within intact genes are not frameshifted.
- **(D)** A transition mutation that creates a stop codon is a *nonsense* mutation, not a frameshift.

Final Answer: Insertion/deletion of nucleotides not in multiples of 3 causes frameshift ⇒ **(B)**

Answer: (B) ↑ Go back to Q 53

Q54.

Solution

Concept — Z-scheme and Oxygen Evolution:
In oxygenic photosynthesis, the **oxygen-evolving complex (OEC)** is a Mn_4CaO_5 cluster located on the lumenal side of **Photosystem II (PSII, P680)**. The OEC splits water:

$$2\,H_2O \longrightarrow O_2 + 4\,H^+ + 4\,e^-$$

The electrons replenish the $P680^+$ reaction centre, which had been oxidised by light absorption. This is the only step in the Z-scheme that *generates* O_2.

Why other options are wrong:

- **(B)** Cytochrome b_6f complex: transfers electrons from PQ to plastocyanin and pumps protons; does not oxidise water.
- **(C)** PSI (P700): receives electrons from PC and reduces ferredoxin; it is the site of NADPH production, not water splitting.
- **(D)** FNR ($NADP^+$ reductase): catalyses the terminal step of electron transfer to $NADP^+$; unrelated to water oxidation.

Final Answer: Photosystem II (P680) oxidises water via the OEC ⇒ **(A)**

Answer: (A) ↑ Go back to Q 54

Solution

Concept — C4 Photosynthesis, Initial Carboxylation:
In C4 plants, CO_2 is first fixed in **mesophyll cells** by **PEP carboxylase** (PEPC, phosphoenolpyruvate carboxylase):

$$\text{PEP} + CO_2 + H_2O \xrightarrow{\text{PEPC}} \text{oxaloacetate (OAA)} + P_i$$

OAA is then reduced to malate or transaminated to aspartate and shuttled to bundle-sheath cells, where CO_2 is released and refixed by RuBisCO.

Why PEPC instead of RuBisCO for the first fixation? PEPC has a very high affinity for CO_2 (low K_m) and *no* oxygenase activity, suppressing photorespiration.

Why other options are wrong:

Q55.

- **(A)** RuBisCO: the C3 carboxylase; in C4 plants it operates only in bundle-sheath cells for the *second* fixation step.
- **(B)** Pyruvate kinase: converts phosphoenolpyruvate to pyruvate during glycolysis; not a carboxylase.
- **(D)** Malate dehydrogenase: converts OAA $\rightarrow$ malate (reduction); comes *after* PEPC, not as the initial CO_2-fixing enzyme.

Final Answer: PEP carboxylase (PEPC) catalyses the initial CO_2 fixation in C4 plants $\Rightarrow$ **(C)**

Answer: (C) ↑ Go back to Q 55

Solution

Concept — Western Blot and Molecular Weight Determination:
In SDS-PAGE, proteins are denatured and coated with SDS (negative charge proportional to mass), so migration is by **size alone**. By comparing the migration distance of an unknown band to a **molecular weight ladder** (pre-stained standards of known MW), one determines the **approximate molecular weight** of the detected protein. In this experiment, the antibody-detected band migrates at $\sim$45 kDa.

Why other options are wrong:

Q56.

- **(A)** mRNA quantity: measured by Northern blot or RT-qPCR, not Western blot.
- **(B)** Isoelectric point (pI): determined by isoelectric focusing (IEF) or 2D-PAGE, not by 1D SDS-PAGE alone.
- **(C)** Copy number per cell: Western blot can give *relative* abundance with a standard curve but a single band position only gives MW, not absolute protein copy number.

Final Answer: The band position indicates the approximate **molecular weight** ($\sim$45 kDa) of the target protein $\Rightarrow$ **(D)**

Answer: (D) ↑ Go back to Q 56

Solution

Concept — Genetic Linkage and Map Distance:
Recombination frequency (RF) is used to estimate genetic map distance: 1% RF $= 1$ centiMorgan (cM). Here, total recombinant offspring $= 6\% + 6\% = 12\%$. Therefore, the two genes are **12 cM apart** on the same chromosome and are

linked (RF $< 50\%$).

Why this confirms linkage: If the genes were on different chromosomes (unlinked), testcross would give 50% recombinants (Mendel's independent assortment). RF = 12% $\ll$ 50%, confirming they are on the same chromosome.

Why other options are wrong:

Q57.

- **(B)** Independent assortment (unlinked) requires RF $= 50\%$; 12% clearly shows linkage.
- **(C)** 12 base pairs: map distance in cM refers to recombination frequency, not physical DNA distance; cM and bp are not equivalent (1 cM $\approx$ 1 Mb in humans but varies).
- **(D)** Cis/trans (coupling/repulsion) phase describes the arrangement of alleles, not the linkage distance; 12% RF is the distance regardless of phase.

Final Answer: The two genes are $\sim$12 cM apart on the same chromosome $\Rightarrow$ **(A)**

Answer: (A) ↑ Go back to Q 57

Solution

Concept — MacArthur-Wilson Equilibrium Model of Island Biogeography: The model (1967) predicts that island species richness reaches a dynamic **equilibrium** (S^*) where:

Q58.

- **Immigration rate** (from mainland) decreases as S increases (fewer new species can arrive as the island fills up).
- **Extinction rate** increases as S increases (more species $\Rightarrow$ more competition and smaller populations $\Rightarrow$ higher extinction risk).

S^* is the point where these two curves **intersect** — the balance between colonisation and extinction.

Key predictions:

- Larger islands have lower extinction rates $\rightarrow$ higher S^* (species-area relationship).
- Islands closer to mainland have higher immigration rates $\rightarrow$ higher S^* (distance effect).

Why other options are wrong:

- **(A)** Immigration rate alone does not determine S^*; without considering extinction, species richness would simply equal the total mainland pool.
- **(B)** Extinction rate alone similarly cannot determine S^*.
- **(D)** Mainland area affects the size of the species pool (immigration rate curve), but S^* is determined by the *intersection* on the target island.

Final Answer: S^* = intersection of immigration and extinction curves $\Rightarrow$ **(C)**

Answer: (C) ↑ Go back to Q 58

Q59.

Solution

Concept — JAK-STAT Signalling Pathway:
When IFN-γ binds its receptor, the receptor dimerises and activates pre-associated **JAK1** and **JAK2** kinases. The activated JAKs **transphosphorylate** each other and then **phosphorylate tyrosine residues** on STAT1 (specifically Tyr-701). Phospho-STAT1 homodimerises (via reciprocal SH2-domain/phospho-tyrosine interactions) and translocates to the nucleus, where it binds GAS (gamma-activated sequence) elements to induce interferon-stimulated genes.

Why other options are wrong:

- **(A)** Ubiquitination of STAT1 would mark it for degradation; this is a regulatory termination mechanism, not the primary activation step.
- **(C)** STATs are not cleaved proteolytically in JAK-STAT signalling; no protease is involved in the canonical pathway.
- **(D)** Acetylation of STAT1 (on Lys) has been reported as a modulatory modification, but phosphorylation of tyrosine is the primary activating event; acetylation alone does not initiate STAT dimerisation.

Final Answer: JAKs phosphorylate STAT1 on Tyr-701, enabling dimerisation and nuclear translocation $\Rightarrow$ **(B)**

Answer: (B) ↑ Go back to Q 59

Q60.

Solution

Concept — Classical Complement Pathway Activation:
The classical pathway is initiated when the recognition subunit **C1q** binds to the Fc regions of antibodies in antigen-antibody complexes. Only certain immunoglobulin isotypes can bind C1q:

- **IgM**: pentameric structure; extremely efficient at activating complement — one bound IgM molecule can activate C1q (five Fc regions available).
- **IgG** (subclasses 1, 2, 3 in humans): monomeric; requires two adjacent Fc regions to cross-link C1q; effective but less potent per molecule than IgM.

IgG vs. IgM activation efficiency: IgM $\gg$ IgG (IgM activates $\sim 1000\times$ more efficiently on a per-molecule basis).

Why other options are wrong:

- **(A)** IgA and IgE: IgA can activate the alternative/lectin pathways; IgE activates mast cells and basophils via FcεRI — neither activates the classical pathway via C1q.

- **(B)** IgD: expressed on naive B cells; essentially no effector function and does not activate complement.
- **(C)** IgA and IgG: IgA does not activate the classical pathway via C1q under normal physiological conditions.

Final Answer: IgG and IgM activate the classical complement pathway via C1q $\Rightarrow$ **(D)**

$\boxed{\textbf{Answer: (D)}}$ ↑ Go back to Q 60

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	A	3	B	4	D	5	C
6	A	7	B	8	D	9	C	10	A
11	B	12	D	13	C	14	A	15	B
16	D	17	C	18	A	19	B	20	D
21	A	22	C	23	B	24	D	25	A
26	C	27	A	28	B	29	D	30	B
31	A	32	C	33	D	34	B	35	A
36	C	37	D	38	B	39	A	40	D
41	B	42	A	43	C	44	D	45	B
46	A	47	C	48	D	49	B	50	A
51	C	52	D	53	B	54	A	55	C
56	D	57	A	58	C	59	B	60	D