

Question 1: In quantum mechanics, Heisenberg uncertainty principle relates position x and momentum p through:

- a) $\Delta x \Delta p \geq \hbar/2$
- b) $\Delta x = \Delta p$ always
- c) $\Delta x \Delta p \leq 0$
- d) No fundamental limit exists

Question 2: In organic chemistry, an SN1 reaction rate depends primarily on:

- a) Concentration of nucleophile only
- b) Stability of carbocation intermediate and concentration of substrate (unimolecular rate-determining step)
- c) Only the temperature but not substrate structure
- d) Pressure only

Question 3: Which method solves Laplace's equation $\nabla^2 \phi = 0$ in simple geometry by separation of variables?

- a) Separation of variables with appropriate Fourier series in chosen coordinates.
- b) Random guesswork only
- c) Using Monte Carlo exclusively
- d) Taylor expansion at zero only

Question 4: A wind farm placement study shows high mean wind speed but also bird migration corridor. Ethically best decision?

- a) Ignore birds and proceed because energy revenue high.
- b) Reassess siting, consider micro-siting, turbine design mitigations, seasonal curtailment, and environmental monitoring to reduce harm while balancing energy goals.
- c) Immediately cancel project without analysis.
- d) Remove monitoring to speed construction.

Question 5: In control systems, a system with characteristic equation roots with positive real parts is:

- a) Stable
- b) Unstable
- c) Marginally stable always
- d) Time-invariant regardless

Question 6: Which numerical integration method provides exact result for polynomials up to degree 3 (cubic) with appropriate nodes?

- a) Trapezoidal rule
- b) Simpson's rule
- c) Midpoint rule
- d) Rectangle rule

Question 7: Which property of a catalytic cycle lowers activation energy of a reaction?

- a) Providing an alternate pathway with lower activation barrier but not consumed in net reaction
- b) Increasing activation energy always
- c) Consuming the catalyst permanently
- d) Eliminating transition state entirely

Question 8: In finite element analysis (FEA), mesh refinement near stress concentrations improves:

- a) Accuracy of local stress predictions
- b) Makes solution independent of boundary conditions only
- c) Decreases model fidelity always
- d) Eliminates need for material properties

Question 9: Which function space best suits weak solutions for second-order elliptic PDEs?

- a) Sobolev spaces (H^1 , etc.) for functions with square-integrable derivatives
- b) Only C^∞ smoothness always required
- c) Discontinuous functions without integrability
- d) Only polynomials permitted

Question 10: A materials scientist needs to choose a solvent for a green synthesis with minimal environmental impact. Which solvent selection criterion is most important?

- a) Low toxicity, high recyclability, low VOC, good solubility/compatibility, and process safety
- b) Cheapest regardless of toxicity.
- c) Solvent with highest boiling point only.
- d) Colour and odour primarily.

Question 11: In differential equations, Sturm–Liouville problems produce eigenfunctions that are:

- a) Orthogonal with respect to a weight function on the domain
- b) Always identical
- c) Non-normalizable always
- d) Random

Question 12: Which renewable energy storage technology has the highest round-trip efficiency typically?

- a) Li-ion batteries (typ. ~85–95% round-trip) — among the highest; pumped hydro ~70–85% depending on site.
- b) Burning biomass always more efficient
- c) Chemical explosives storage
- d) Unregulated open fires

Question 13: In organic spectroscopy, multiplicity (splitting) in ^1H NMR is explained by:

- a) Spin–spin coupling between non-equivalent neighbouring protons
- b) Magnetic susceptibility
- c) Molecular weight
- d) Solubility

Question 14: Which concept in calculus ensures existence and uniqueness for solution of $y' = f(x, y)$ with initial condition $y(x_0) = y_0$?

- a) Picard–Lindelöf theorem
- b) No theorem exists
- c) Only linear ODEs have solutions
- d) Divergence theorem

Question 15: A coastal engineering model predicts storm surge levels with uncertainty. To communicate risk to city planners you should:

- a) Provide probabilistic scenarios, confidence intervals, worst-case plausible outcomes, sensitivity analysis, and adaptation options.
- b) Give a single deterministic number without uncertainty.
- c) Hide uncertainty to avoid panic.
- d) Provide only historical anecdotes.

Question 16: In quantum devices, decoherence is mainly caused by:

- a) Interaction with environment leading to loss of phase coherence between quantum states
- b) Perfect isolation in vacuum
- c) Using superconductors always removes decoherence completely
- d) Decoherence is only speculative

Question 17: Which method is commonly used to solve non-linear least squares in parameter estimation?

- a) Gauss–Newton or Levenberg–Marquardt algorithms
- b) Exact algebraic closed form always exists
- c) Sorting data
- d) Use of logarithms

Question 18: In environmental engineering, biochemical oxygen demand (BOD) measurement indicates:

- a) Amount of oxygen consumed by biological decomposition of organic matter over a specified period
- b) Only dissolved oxygen concentration instant reading
- c) pH value directly
- d) Turbidity only

Question 19: Which advanced integration technique is used to handle oscillatory integrals in applied maths?

- a) Stationary phase method / steepest descent for highly oscillatory integrals
- b) Basic Riemann sums
- c) Trapezoidal rule
- d) Simpson's rule

Question 20: A prototype autonomous vehicle shows intermittent sensor dropouts at low temperatures. Best engineering step?

- a) Evaluate sensor operating temperature range, add heating or environmental control for sensors, and use redundancy and sensor fusion to tolerate dropouts.
- b) Ignore issue; operate only in summer.
- c) Replace entire vehicle.
- d) Remove all sensors.

Question 21: In reaction thermodynamics, Gibbs free energy $G = H - TS$ indicates spontaneity under constant:

- a) Pressure and temperature
- b) Volume
- c) Entropy
- d) Pressure

Question 22: Which method solves linear systems $Ax = b$ efficiently for large sparse symmetric positive-definite matrices?

- a) Conjugate gradient
- b) Gaussian elimination dense LU for huge sparse matrices
- c) Bubble sort analogy
- d) FFT based direct

Question 23: Which phenomenon explains thermal runaway in lithium-ion batteries?

- a) Exothermic side reactions that accelerate with temperature causing further heating (positive feedback)
- b) Endothermic stabilization always
- c) Photosynthesis inside cells
- d) Magnetic levitation

Question 24: In PDE classification, wave equation $\partial^2 u / \partial t^2 = c^2 \partial^2 u / \partial x^2$ is:

- a) Elliptic
- b) Parabolic
- c) Hyperbolic
- d) Ordinary

Question 25: An experimental chemist uses a polar aprotic solvent and observes increased SN2 reactivity compared to protic solvent.

Explanation:

- a) Polar aprotic solvents solvate cations but not anions, increasing nucleophilicity of anionic nucleophiles and enhancing SN2 rates.
- b) Polar aprotic solvents always decrease reaction rates.
- c) Solvents have no effect on mechanism.
- d) Reaction must be radical in aprotic solvents.

Question 26: In advanced calculus, a function with absolutely convergent Fourier series ensures:

- a) Absolute convergence implies uniform convergence of the Fourier series.
- b) Divergence everywhere
- c) Only pointwise convergence always fails
- d) No integrability

Question 27: Which engineering design stage focuses on detailed drawings, tolerances, and manufacturing specifications?

- a) Conceptual design
- b) Detailed design / development
- c) Ideation
- d) Marketing stage

Question 28: An ML team faces model drift after deployment due to no stationary user behaviour. Which governance step is most critical?

- a) Implement continuous monitoring for performance and data drift, set triggers for retraining, and maintain model versioning and rollback strategies.
- b) Ignore drift and hope for best.
- c) Use only one model forever.
- d) Disable logging.

Question 29: Which thermodynamic relation gives Maxwell relations?

- a) Relations derived from equality of mixed second derivatives of thermodynamic potentials (e.g., from dG , dA)
- b) Derived by integrating entropy
- c) Random empirical laws
- d) Only valid for ideal gases

Question 30: In numerical PDEs, CFL condition ensures stability for explicit schemes and relates:

- a) Time step Δt , spatial step Δx , and wave speed
- b) Only spatial step matters
- c) Only time step matters without relation to spatial discretization
- d) CFL is only for elliptic problems

Question 31: A student uses cross-over experimental design to compare two fertilizers.

Main advantage?

- a) Each plot receives both treatments at different times so each acts as its own control; reduces inter-plot variability.
- b) Cross-over design always invalid for agriculture.
- c) Only increases bias.
- d) Removes need for replication.

Question 32: Which spectroscopy technique determines molecular vibrational modes?

- a) Infrared (IR) spectroscopy and Raman spectroscopy
- b) NMR only
- c) UV-Vis only
- d) Mass spectrometry only

Question 33: In linear control theory, state feedback can place closed-loop poles provided:

- a) System is controllable
- b) System is always controllable regardless of matrices
- c) Observability irrelevant only
- d) Only using open-loop

Question 34: An environmental impact assessment shows increased downstream turbidity from construction. Mitigation best practice?

- a) Sediment control measures (silt fences, settling ponds), timing work for low-flow periods, and erosion control on slopes.
- b) Dump dredged material into river.
- c) Ignore turbidity; it clears itself.
- d) Remove all aquatic life.

Question 35: Which mathematical method finds approximate eigenvalues of large matrices with sparse structure?

- a) Lanczos algorithm or Arnoldi iteration (Krylov subspace methods)
- b) Direct diagonalization dense
- c) Use Gaussian quadrature only
- d) Permutation of rows randomly

Question 36: In chemical equilibrium, Le Chatelier's principle predicts that increasing pressure will shift equilibrium toward:

- a) Side with fewer moles of gas (if gaseous species present)
- b) Side with more gas moles
- c) There is no shift with pressure changes
- d) Only temperature matters

Question 37: A bridge design uses high-strength steel but local contractors lack welding expertise for that grade. Best course?

- a) Provide training or choose materials/processes compatible with local fabrication capabilities, factoring lifecycle costs and quality control.
- b) Ignore fabrication constraints and hope for the best.
- c) Import fully built bridge only.
- d) Use untested welding methods.

Question 38: Which PDE boundary condition specifies derivative value at boundary?

- a) Dirichlet
- b) Neumann
- c) Robin
- d) Periodic only

Question 39: Which algorithmic problem is NP-complete (commonly taught advanced CS topics)?

- a) Traveling Salesman Problem (decision version) and other combinatorial problems (e.g., SAT) are canonical NP-complete/NP-hard problems.
- b) Sorting in $O(n \log n)$
- c) Matrix multiplication polynomial-time trivial
- d) Binary search complexity trivial

Question 40: A lab reaction emits noxious fumes; immediate safety step?

- a) Evacuate area, use fume hood/ventilation, don appropriate PPE, and follow spill/emergency response protocols.
- b) Continue working faster to finish.
- c) Ignore exposure.
- d) Turn off lights only.

Question 41: In optimization, Karush–Kuhn–Tucker (KKT) conditions provide:

- a) First-order necessary conditions for optimality in nonlinear programming with constraints (generalization of Lagrange multipliers)
- b) Only for unconstrained linear problems
- c) Provide sufficient conditions without convexity
- d) Replace differential equations entirely

Question 42: Which atmospheric pollutant is primary contributor to acid rain?

- a) SO₂ and NO_x emissions (sulphur dioxide and nitrogen oxides) oxidize to form sulphuric and nitric acids
- b) CO₂ only
- c) O₂ only
- d) N₂ only

Question 43: A student finds their numerical simulation is unstable for large time steps.

Which immediate fix is prudent before major redesign?

- a) Reduce time step to satisfy stability constraint or switch to an implicit scheme with larger stable time steps.
- b) Increase time step further; hope for stability.
- c) Turn off outputs.
- d) Change language to one with different keywords.

Question 44: In supramolecular chemistry, host–guest complexes are stabilized primarily by:

- a) Covalent bond formation only
- b) Noncovalent interactions (hydrogen bonding, van der Waals, hydrophobic, electrostatic) and complementarity of shapes
- c) Metallic bonds only
- d) Radioactivity

Question 45: Which derivation uses separation of variables for heat conduction in a rod with insulated ends?

- a) Leads to cosine series solutions (Neumann-type eigenfunctions)
- b) Always sine series
- c) Uniform constant solutions
- d) Polynomial solutions

Question 46: A pilot plant scale-up shows exotherm not controlled as in lab. Which design step is essential?

- a) Re-examine heat transfer coefficient, reactor geometry, mixing, and include safety interlocks and emergency quench systems in scale-up design.
- b) Scale up linearly without thermal analysis.
- c) Increase batch size without analysis.
- d) Ignore heat removal.

Question 47: In reaction kinetics, the Arrhenius equation $k = A e^{-E_a/RT}$ shows that increasing temperature generally:

- a) Decreases rate constant k
- b) Increases k exponentially depending on activation energy E_a
- c) Has no effect on k
- d) Reduces reaction yield

Question 48: Which numerical linear algebra preconditioning improves convergence of iterative solvers?

- a) Use an appropriate preconditioned M approximating A^{-1} to transform system into better-conditioned form $(M^{-1}A)$
- b) Use no preconditioning
- c) Randomize rows only
- d) Reduce precision arbitrarily

Question 49: Designing a sedimentation tank, which factor most affects settling velocity of particles?

- a) Particle size, density difference, fluid viscosity, and flow conditions (Stokes' law regime)
- b) Colour of tank only
- c) Number of operators present
- d) Brand of pump only

Question 50: Which theorem relates Fourier transforms and convolution?

- a) Convolution theorem
- b) Pythagoras only
- c) Mean value theorem only
- d) No relation exists

Question 51: Which battery chemistry currently offers highest energy density for many applications?

- a) Lithium-ion chemistries (various formulations) generally have high battery energy density
- b) Lead-acid highest always
- c) Nickel-cadmium highest always
- d) Zinc-carbon highest always

Question 52: You must estimate uncertainty propagation for function $f(x,y) = x/y$ with uncertainties of x and y . Best approach?

- a) Use partial derivatives (first-order Taylor propagation) to approximate combined uncertainty, or Monte Carlo propagation for nonlinear cases.
- b) Ignore uncertainties.
- c) Add uncertainties linearly always.
- d) Multiply uncertainties without derivatives.

Question 53: In structural engineering, buckling of a slender column under compressive load is predicted by:

- a) Euler's critical load formula $P_{cr} = \pi^2 EI / (KL)^2$ where K is effective length factor (depends on end conditions).
- b) Hooke's law only unrelated
- c) Thermodynamic entropy formula
- d) Bernoulli's equation exclusively

Question 54: Which property makes polymers glassy at room temperature?

- a) Glass transition temperature T_g higher than room temperature leading to amorphous glassy state
- b) Crystallinity only always leads glassy
- c) Low molecular weight only
- d) Presence of metals only

Question 55: A proposed wastewater reuse scheme for irrigation must ensure public health. Key microbiological control measure?

- a) Adequate disinfection (chlorination/UV), multi-barrier approach, monitoring for pathogens, and adherence to WHO/ national guidelines on reuse.
- b) Dilute untreated sewage with fresh water only.
- c) No treatment required for irrigation.
- d) Only filtration without disinfection.

Question 56: In optimization, convexity of objective and feasible region ensures:

- a) Any local minimum is also global minimum (convex problems easier to solve reliably)
- b) Local minima are always worse than global minima
- c) No minima exist
- d) Multiple disconnected solutions only

Question 57: Which statistical distribution often models count of rare events in fixed interval?

- a) Poisson distribution
- b) Normal
- c) Uniform only
- d) Binomial never

Question 58: A city monitors CO_2 trends and sees an annual upward trend but large seasonal oscillations. How best to analyse underlying anthropogenic trend?

- a) Decompose time series into seasonal component and trend (e.g., use seasonal decomposition, moving averages, or regression with seasonal dummies) to isolate long-term trend.
- b) Average whole series ignoring seasonality only.
- c) Use single yearly value only.
- d) Remove seasonal months arbitrarily.

Question 59: Which method estimates molecular geometry and electronic structure approximately with good cost/accuracy for moderate systems?

- a) Density Functional Theory (DFT) commonly used in computational chemistry for balance of cost and accuracy
- b) Classical mechanics only
- c) Purely empirical with no quantum treatment only
- d) Random guesses

Question 60: Which type of chemical structure generally enhances biodegradability of an organic compound?

- a) Simple, linear hydrocarbons without halogenation
- b) Heavily halogenated aromatic compounds
- c) Highly branched polymers with cross-linking
- d) Organometallic complexes with heavy metals

ROUGH WORK

(NOT TO BE EVALUATED)

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