

Question 1: In special relativity, two events separated by a spacelike interval can be ordered differently by different inertial observers. Which physical statement follows?

- a) They can be connected by a signal traveling slower than light.
- b) No causal influence can propagate between them.
- c) They must occur at the same place in all frames.
- d) Their time order is absolute.

Question 2: In organic synthesis, a protecting group is used primarily to:

- a) Change the stereochemistry of the functional group.
- b) Temporarily mask a reactive site to allow selective reaction elsewhere.
- c) Increase the overall reaction rate of all groups.
- d) Permanently block a site for the rest of synthesis.

Question 3: A heat engine operates between 600 K and 300 K and achieves 40% thermal efficiency. Which statement is correct?

- a) It achieves greater efficiency than a Carnot engine between those reservoirs.
- b) It is impossible because Carnot limit for these temperatures is 50%; 40% is feasible.
- c) It violates the second law of thermodynamics.
- d) Efficiency must equal $1 - (T_{\text{hot}}/T_{\text{cold}})$.

Question 4: For the differential equation $dy/dx + P(x)y = Q(x)$, the integrating factor is:

- a) $e^{\int P(x) dx}$
- b) $\int Q(x) dx$
- c) $e^{P(x)}$
- d) $1/P(x)$

Question 5: In quantum information, a qubit in state $(|0\rangle + |1\rangle)/\sqrt{2}$ measured in computational basis yields:

- a) Always $|0\rangle$ with probability 1.
- b) $|0\rangle$ or $|1\rangle$ each with probability 1/2.
- c) A deterministic value of 0.5.
- d) Collapse to an orthogonal state.

Question 6: In environmental engineering, which process primarily removes biological oxygen demand (BOD) from wastewater?

- a) Sedimentation only
- b) Biological treatment
- c) Chlorination exclusively
- d) Simple filtration through sand

Question 7: A researcher models a reaction with ΔG° positive under standard conditions but notes ΔG becomes negative at high reactant concentration. Which is correct?

- a) Reaction spontaneity cannot change with concentration.
- b) Reaction can become spontaneous under non-standard conditions when Q changes such that $\Delta G = \Delta G^\circ + RT \ln Q$ becomes negative.
- c) ΔG° is the only determinant and cannot be altered.
- d) Concentration changes only affect reaction rate, not spontaneity.

Question 8: In machine design, factor of safety (FoS) of a component is the ratio of:

- a) Yield stress to applied stress (or allowable stress to working stress)
- b) Applied stress to yield stress
- c) Elastic modulus to yield stress
- d) Ultimate load to stiffness

Question 9: Which algorithmic complexity describes solving $n \times n$ linear system using Gaussian elimination (naïve)?

- a) $O(n \log n)$
- b) $O(n^3)$
- c) $O(n^2)$
- d) $O(2^n)$

Question 10: In thermodynamics, the Hess's law statement implies:

- a) Enthalpy change for a reaction depends on the path taken.
- b) Enthalpy change is path independent; it is a state function.
- c) Entropy is always conserved.
- d) Gibbs free energy is independent of temperature.

Question 11: You design an eco-friendly building and want to minimize embodied carbon. Which strategy is most effective?

- a) Increase glass facade area for aesthetics.
- b) Choose low-carbon materials (timber from sustainable sources, low-carbon concrete mixes), optimize material quantity, and design for durability and reuse.
- c) Use exotic metals regardless of sourcing.
- d) Ignore insulation to save on initial cost.

Question 12: Which of the following is a necessary condition for a second-order linear ODE $y'' + p(x)y' + q(x)y = 0$ to have two linearly independent solutions near x_0 ?

- a) Wronskian nonzero at x_0
- b) $p(x_0) = 0$ only
- c) $q(x_0) = 0$ only
- d) Solutions must be polynomials

Question 13: In spectroscopy of organic molecules, a strong peak near 1700 cm^{-1} in IR typically indicates:

- a) O–H stretch of alcohol
- b) C=O stretch (carbonyl)
- c) C–H sp^3 stretch
- d) N–H bend

Question 14: Which quantum mechanical operator corresponds to the observable “momentum” in one dimension?

- a) $-\hbar \partial/\partial x$
- b) $\hbar \partial/\partial x^2$
- c) Multiplication by x
- d) Laplacian in time

Question 15: A small experimental design has low statistical power. Which remedy is most appropriate to increase power without changing effectsize?

- a) Reduce sample size further.
- b) Increase sample size, reduce measurement noise, or use a more powerful statistical test / paired design if applicable.
- c) Use more variables arbitrarily.
- d) Change hypothesis direction mid-study.

Question 16: In organic chemistry, Markovnikov’s rule predicts regiochemistry of addition to alkenes due to:

- a) Stability of intermediate carbocation (more substituted carbocation favoured)
- b) Steric hindrance always forcing addition to less substituted carbon
- c) Random distribution of addends
- d) Electron donation by solvent only

Question 17: For an ideal rocket, the specific impulse (Isp) relates to:

- a) Thrust per unit mass flow of propellant
- b) Mass of rocket only
- c) Absolute pressure in chamber only
- d) Payload mass only

Question 18: A river catchment project must reduce nutrient (nitrogen) loading to downstream lake. Which integrated measure is likely most effective?

- a) Build only a single large infiltration pond near outlet.
- b) Combine riparian buffer zones, constructed wetlands, controlled fertilizer application upstream, and stormwater detention to reduce and transform nitrogen loads.
- c) Remove all vegetation to reduce uptake.
- d) Increase impervious surfaces to speed flow.

Question 19: Which linear algebra concept is used to diagonalize a symmetric matrix?

- a) Schur decomposition only
- b) Orthogonal eigen-decomposition
- c) Jordan normal form with complex rotation only
- d) Use of LU decomposition alone

Question 20: In Advanced Calculus, which condition ensures uniform convergence of a sequence of functions f_n to f on a set?

- a) For every $\epsilon > 0$ there exists N such that for all $n \geq N$ and all x in set, $|f_n(x) - f(x)| < \epsilon$ (uniform in x)
- b) Pointwise convergence at each x (N may depend on x)
- c) Convergence in measure only
- d) Only boundedness is needed

Question 21: A lab reports systematic error in measurements due to a miscalibrated instrument. To correct historic data, you should:

- a) Ignore and publish as-is.
- b) Recalibrate instrument, quantify bias via calibration curve, apply correction to data with propagated uncertainty, and document adjustments.
- c) Replace data arbitrarily.
- d) Remove all data points.

Question 22: In environmental engineering, the 3Rs stand for:

- a) Reduce, Reuse, Recycle
- b) Read, React, Repeat
- c) Repair, Return, Reclaim only
- d) Residue, Reactant, Reagent

Question 23: In PDEs, the heat equation $\partial u / \partial t = \alpha \partial^2 u / \partial x^2$ is classified as:

- a) Elliptic PDE
- b) Parabolic PDE
- c) Hyperbolic PDE
- d) Ordinary differential equation

Question 24: Which mechanism best explains hydrogen bonding in water?

- a) Covalent sharing of electrons equally between molecules
- b) Electrostatic attraction between partially positive hydrogen on one molecule and partially negative lone pair on oxygen of another
- c) Ionic bonding between hydrogen and oxygen across molecules
- d) Metallic bonding

Question 25: You propose to build a small autonomous drone for environmental monitoring. For safety and compliance, which design consideration is most important early in project?

- a) Ignore local airspace regulations.
- b) Consider weight, fail-safe flight control, geofencing, communication security, battery safety, and regulatory approvals (airspace, privacy).
- c) Maximize speed disregarding reliability.
- d) Omit telemetry to reduce cost.

Question 26: In thermochemistry, ΔH°_f of formation for an element in standard state is:

- a) Nonzero positive always
- b) Zero by convention
- c) Undefined
- d) Equal to entropy

Question 27: Which mathematical test can check whether a series $\sum a_n$ converges absolutely?

- a) Ratio test or root test applied to $|a_n|$
- b) Only comparison to harmonic series is allowed always
- c) Convergence of a_n to zero is sufficient
- d) Divergence test

Question 28: An engineer must optimize a cantilever beam for minimum deflection under given load and mass constraint. Which design method is most appropriate?

- a) Trial and error with random materials only
- b) Use variational principles or constrained optimization techniques (Lagrange multipliers) and material property selection / cross-section optimization.
- c) Increase length indefinitely.
- d) Ignore boundary conditions.

Question 29: In spectroscopy, NMR chemical shift is sensitive to:

- a) Electronic environment of nuclei (shielding/deshielding)
- b) Only molecular mass
- c) Presence of IR-active modes only
- d) Solid-state colour

Question 30: Which statement about relativistic mass is considered obsolete in modern physics pedagogy?

- a) Use of invariant rest mass (rest energy $E_0 = mc^2$) and treat relativistic energy/momentum rather than invoking velocity-dependent "relativistic mass."
- b) Relativistic mass increases without changing energy notions.
- c) Mass is undefined.
- d) Mass and charge are identical.

Question 31: You run a controlled ecological experiment and see large variability between replicates. What step increases reliability?

- a) Reduce number of replicates to speed up.
- b) Increase replication, standardize protocols, randomize assignment, and control confounding variables.
- c) Pool all replicates without analysis.
- d) Change the measurement units only.

Question 32: In organic reaction mechanisms, a pericyclic reaction proceeds via:

- a) Concerted cyclic transition state with orbital symmetry considerations (Woodward–Hoffmann rules)
- b) Free radical chain always only
- c) Ionic substitution only
- d) Stepwise with stable carbocation necessarily

Question 33: Which numerical method is appropriate to approximate solutions to initial value problems with stiff ODEs?

- a) Explicit Euler always best
- b) Implicit methods (Backward Euler, implicit Runge-Kutta) or tailored stiff solvers
- c) Unstable step-size only
- d) Monte Carlo sampling only

Question 34: A chemical synthesis route gives low yield and a major by-product. Which practical approach improves yield?

- a) Change to more selective reagent, alter reaction conditions (temp/solvent), use protecting groups, or adopt different pathway with better chemo- and regioselectivity.
- b) Increase reaction time indefinitely regardless of side reactions.
- c) Ignore purification and assume product is pure.
- d) Reduce reactant purity arbitrarily.

Question 35: In engineering drawing, tolerance specifies:

- a) Acceptable variation in manufactured dimension (upper and lower limits)
- b) Maximum speed of machine only
- c) Chemical tolerance to reagents
- d) Aesthetic preference only

Question 36: Which conservation law corresponds to symmetry under spatial translations (Noether's theorem)?

- a) Conservation of energy
- b) Conservation of linear momentum
- c) Conservation of charge
- d) Conservation of angular momentum

Question 37: A sustainability assessment uses Life Cycle Assessment (LCA). Which stages are included?

- a) Raw material extraction, manufacturing, use phase, and end-of-life (recycling/disposal) — cradle-to-grave analysis.
- b) Use phase only.
- c) Only marketing stage.
- d) Only disposal stage.

Question 38: For Fourier transform of a time-domain signal to exist (in classical sense), a sufficient condition is:

- a) Signal is absolutely integrable ($\int |f(t)| dt < \infty$)
- b) Signal is unbounded for all t
- c) Signal has no discontinuities only
- d) Signal is periodic only

Question 39: Which concept best describes entropy in statistical mechanics?

- a) Number of accessible microscopic states consistent with macroscopic constraints (Boltzmann multiplicity)
- b) Energy content alone
- c) Volume only
- d) Pressure exclusively

Question 40: A wastewater treatment plant operator notes nitrification failure in the aerobic tanks. Which troubleshooting step is appropriate?

- a) Check dissolved oxygen (DO), pH, temperature, toxic inhibitors, and sludge age; adjust aeration and return activated sludge rates to restore nitrifies.
- b) Remove aerators and stop oxygen supply.
- c) Add only chlorine to kill bacteria.
- d) Empty tanks and fill with fresh water.

Question 41: Which eigenvalue problem arises when solving vibrating strings with fixed ends?

- a) Sturm
- b) No eigenvalues involved
- c) Only algebraic equations
- d) Random Fourier coefficients

Question 42: In materials engineering, fatigue failure is mainly due to:

- a) Static overload only
- b) Repeated cyclic stresses causing crack initiation and propagation below ultimate tensile strength
- c) Corrosion only
- d) Elastic deformation always

Question 43: A student must present a poster on climate resilience for a coastal city. Which combination of solutions is most robust?

- a) Only seawalls with no community planning.
- b) Nature-based solutions managed retreat where needed, early warning systems, and resilient infrastructure combined.
- c) Abandon all inhabitants.
- d) Build high-rise concrete towers only.

Question 44: In calculus of variations, the Euler–Lagrange equation gives:

- a) Condition for stationary value (minimum/maximum/ extremum) of a functional
- b) Only algebraic roots
- c) Random steps for integration
- d) Derivative of a function squared

Question 45: Which principle guides green chemistry to reduce environmental harm?

- a) Use of stoichiometric excess and toxic reagents whenever possible
- b) Design safer chemicals, reduce waste, use renewable feedstocks and energy-efficient processes
- c) Never consider lifecycle impacts
- d) Focus only on product colour

Question 46: You design an experiment comparing two teaching methods. To avoid bias, you should:

- a) Randomly assign students to groups, blind evaluators where possible, and use standardized assessment instruments.
- b) Let students choose groups freely.
- c) Assign highest-performers to one group only.
- d) Use different tests for each group.

Question 47: Which thermodynamic potential is minimized at constant temperature and volume?

- a) Gibbs free energy G
- b) Helmholtz free energy A (or F)
- c) Enthalpy H
- d) Internal energy minus pressure-volume term only

Question 48: In numerical linear algebra, condition number of matrix A measures:

- a) Sensitivity of solution to $Ax = b$ with respect to perturbations in b (ill-conditioning)
- b) Number of nonzero elements only
- c) Determinant sign only
- d) Rank only

Question 49: A proposed renewable energy micro grid needs to integrate solar PV with battery storage. For sizing battery storage which factor is most critical?

- a) Average summer temperature only
- b) Load profile, desired autonomy period, depth of discharge, round-trip efficiency, and charge/discharge rates
- c) Colour of panels
- d) Number of installers available

Question 50: In chemical kinetics, for a first-order reaction, the concentration decay follows:

- a) Linear decrease with time
- b) Exponential decay: $[A] = [A]_0 e^{-kt}$
- c) Quadratic polynomial decay
- d) Oscillatory behaviour

Question 51: Which of the following defines Reynolds number Re in fluid mechanics?

- a) $Re = \rho v L / \mu$ (ratio of inertial to viscous forces)
- b) $Re = v^2 / g$ only
- c) $Re = \text{pressure} \times \text{volume}$
- d) $Re = \text{kinematic viscosity only}$

Question 52: A researcher claims a breakthrough but provides $p\text{-value} = 0.051$ in a small sample. How to interpret responsibly?

- a) Treat as “not statistically significant” at $\alpha=0.05$, report effect size and confidence intervals, consider further studies and avoid over claiming.
- b) Announce discovery as definitive.
- c) Change α to 0.1 post-hoc to claim significance without justification.
- d) Hide the $p\text{-value}$.

Question 53: In differential equations, the Laplace transform is especially useful for solving:

- a) Linear ODEs with constant coefficients and given initial values
- b) Nonlinear PDEs only
- c) Algebraic equations only
- d) Integration by parts replacement only

Question 54: Which atmospheric engineering approach reduces urban heat island effect most directly?

- a) Increase impervious asphalt coverage downtown
- b) Increase urban green cover, cool roofs, reflective pavements, and integrate water bodies
- c) Remove all trees to reduce transpiration
- d) Paint everything black

Question 55: You measure an unknown sample's heat capacity calorimetrically and observe an unexpectedly high heat capacity. Possible causes include:

- a) Sample contains water or bound moisture, heat losses to surroundings, incorrect mass measurement, or instrumental calibration error. Investigate and correct.
- b) Always assume sample is exotic material.
- c) Ignore result.
- d) Reuse instrument without calibration.

Question 56: In eigenfunction expansions for PDEs, orthogonality of eigenfunctions ensures:

- a) Coefficients in series can be determined by inner-product projections and independence of modes
- b) They are identical functions
- c) Orthogonality is irrelevant
- d) All eigenvalues are equal

Question 57: Which process best removes phosphates from wastewater?

- a) Chemical precipitation and biological uptake
- b) Simple sieving only
- c) UV irradiation only
- d) Evaporation only

Question 58: A student models pollutant dispersion with Gaussian plume model but near complex terrain it fails. Best next step:

- a) Use more advanced CFD modelling including terrain effects, or use computationally feasible dispersion models that include complex flow, and validate with field data.
- b) Continue using Gaussian plume without validation.
- c) Assume pollutants vanish near hills.
- d) Ignore terrain and only sample at single point.

Question 59: Which mathematical technique is central to solving eigenvalue problems in quantum wells?

- a) Solving Schrödinger equation with boundary conditions to obtain quantized energy eigenvalues
- b) Using only Fourier series for polynomials
- c) Ignoring boundary conditions
- d) Using Euler's totient theorem

Question 60: Which of the following best characterizes bioaccumulation in the environment?

- a) Increase in concentration of a substance in organisms over time, often up the food chain (biomagnification)
- b) Rapid evaporation of pollutants only
- c) Instant neutralization of toxins in water
- d) Decrease of concentration through photosynthesis only

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