OJEE M Tech Chemical Sample Paper 03

A) Mode and Time: The exam is a Computer Based Test (CBT) lasting 120 minutes.
B) Total Questions: The exam contains 90 questions.
C) Marking Scheme & Rules:

- +4 for correct answers and -1 for incorrect responses.

Q1. The value of $\lim_{x\to 0} \frac{\tan x - x}{x^3}$ is:

A. 0

B. 1/3

C. 1/2

D. 1

Q2. If A is an idempotent matrix ($A^2 = A$), the only possible eigenvalues of A are:

A. 0 and 1

B. -1 and 1

C. 0 and -1

D. Complex conjugates

Q3. The inverse of a real orthogonal matrix is always equal to its:

A. Adjoint

B. Determinant

C. Transpose

D. Conjugate

Q4. The directional derivative of the scalar field $\phi(x, y, z) = x^2y + xz$ at the point $(1, 2, -1)$ in the direction of the vector $2\mathbf{i} - 2\mathbf{j} + \mathbf{k}$ is:

A. 1

B. 5/3

C. 3

D. 7/3

Q5. The value of the double integral $\int_0^1 \int_0^x e^{y/x} dydx$ is:

A. $e - 1$

B. $\frac{1}{2}(e - 1)$

C. e

D. $\frac{1}{2}e$

Q6. Using Cauchy's Integral Formula, the value of $\oint_C \frac{e^z}{z-\pi i} dz$ around the contour $|z| = 4$ is:

A. 0

B. $2\pi i$

C. $-2\pi i$

D. πi

Q7. The general solution to the second-order differential equation $y'' - 2y' + y = 0$ is:

A. $y = c_1 e^x + c_2 e^{-x}$

B. $y = c_1 \cos x + c_2 \sin x$

C. $y = (c_1 + c_2 x)e^x$

D. $y = c_1 e^x + c_2 x e^{-x}$

Q8. The Laplace transform of $f(t) = t^n$ (where n is a positive integer) is:

A. $\frac{n!}{s^n}$

B. $\frac{n!}{s^{n+1}}$

C. $\frac{1}{s^{n+1}}$

D. $\frac{n}{s^{n+1}}$

Q9. The error in the Trapezoidal rule for numerical integration is proportional to:

A. h

B. h^2

C. h^3

D. h^4

Q10. Two fair dice are rolled simultaneously. The probability that the sum of the numbers appearing on top is 8 is:

A. 1/6

B. $5/36$

C. $7/36$

D. $1/9$

Q11. The curl of the gradient of any twice-differentiable scalar field ϕ is strictly:

A. 1

B. 0

C. $\nabla^2\phi$

D. $\nabla\phi$

Q12. The roots of the Euler-Cauchy equation $x^2y'' - 2xy' + 2y = 0$ dictate that the solution is of the form:

A. $c_1x + c_2x^2$

B. $c_1e^x + c_2e^{2x}$

C. $c_1 \ln x + c_2x$

D. $c_1x + c_2x^{-2}$

Q13. The residue of the complex function $f(z) = \frac{1}{z^2+1}$ at the pole $z = i$ is:

A. i

B. $-i$

C. $1/2i$

D. $-1/2i$

Q14. For a continuous uniform random variable distributed between a and b, the mean is:

A. $a + b$

B. $(a + b)/2$

C. $(b - a)/2$

D. $ab/2$

Q15. The maximum value of the function $f(x) = xe^{-x}$ for $x > 0$ occurs at:

A. $x = 1$

B. $x = e$

C. $x = 0$

D. $x = 1/e$

Q16. According to the Intermediate Value Theorem, the polynomial $x^3 - x - 1 = 0$ must have a real root in the interval:

A. [-1, 0]

B. [0, 1]

C. [1, 2]

D. [2, 3]

Q17. If A is an $m \times n$ matrix with rank r, the dimension of the null space (nullity) of A is:

A. $m - r$

B. $n - r$

C. r

D. $m \times n - r$

Q18. The integrating factor for the linear first-order differential equation $y' + y = x$ is:

A. x

B. x^2

C. e^x

D. e^{-x}

Q19. The value of the Gamma function $\Gamma(1/2)$ is:

A. 1

B. π

C. $\sqrt{\pi}$

D. $\pi/2$

Q20. If A and B are two events such that $P(B) > 0$, the conditional probability $P(A|B)$ is equal to:

A. $P(A)P(B)$

B. $P(A \cap B)/P(A)$

C. $P(A \cup B)/P(B)$

D. $P(A \cap B)/P(B)$

Q21. Identify the next term in the series: 1, 4, 27, 16, 125, 36, ...

A. 49

B. 216

C. 343

D. 64

Q22. A's mother is the sister of B and has a daughter C. How is B related to C?

A. Uncle or Aunt

B. Niece

C. Cousin

D. Brother

Q23. If in a certain code, "CAT" is equal to 24 and "DOG" is equal to 26, what will "RAT" be equal to?

A. 36

B. 38

C. 39

D. 42

Q24. A person walks 10 m North, turns right and walks 20 m, turns right again and walks 10 m, then turns left and walks 10 m. How far and in which direction is he from the start?

A. 30 m East

B. 20 m West

C. 30 m North

D. 20 m East

Q25. Statements: Some A are B. All B are C. Conclusion: Some A are C.

A. True

B. False

C. Cannot be determined

D. Irrelevant

Q26. What is the probability that a randomly selected leap year has exactly 53 Sundays?

A. 1/7

B. 2/7

C. 3/7

D. 1/366

Q27. In a queue, Rohan is 10th from the front and 20th from the back. How many people are in the queue?

A. 29

B. 30

C. 31

D. 28

Q28. Find the odd one out among the following celestial bodies:

A. Mercury

B. Venus

C. Moon

D. Mars

Q29. A car travels from city A to B at 40 km/hr and returns from B to A at 60 km/hr. The average speed for the round trip is:

A. 50 km/hr

B. 48 km/hr

C. 45 km/hr

D. 52 km/hr

Q30. What is the angle between the hour hand and the minute hand of a clock exactly at 3:30?

A. 75°

B. 90°

C. 105°

D. 60°

Q31. At very low pressures, the fugacity of a pure liquid is approximately equal to its:

A. Critical pressure

B. Atmospheric pressure

C. Vapor pressure

D. Zero

Q32. The residual volume V^R of an ideal gas at any temperature and pressure is strictly:

A. Infinity

B. RT/P

C. 0

D. 1

Q33. The Clausius-Clapeyron equation is derived by making the fundamental assumption that:

A. The gas is non-ideal

B. The liquid volume is negligible compared to the vapor volume

C. The latent heat varies logarithmically

D. The process is isothermal

Q34. At the thermodynamic critical point of a substance, the latent heat of vaporization becomes:

A. Infinity

B. Maximum

C. Zero

D. Equal to specific heat

Q35. The Coefficient of Performance (COP) of an ideal Carnot refrigerator operating between T_h and T_c is given by:

A. $T_h/(T_h - T_c)$

B. $T_c/(T_h - T_c)$

C. $(T_h - T_c)/T_c$

D. $1 - T_c/T_h$

Q36. For a Newtonian fluid, the shear stress is strictly proportional to the:

A. Velocity gradient

B. Pressure gradient

C. Density gradient

D. Viscosity gradient

Q37. In boundary layer theory, flow separation from a solid surface is fundamentally triggered by:

A. A favorable pressure gradient

B. An adverse pressure gradient

C. Zero pressure gradient

D. Laminar to turbulent transition

Q38. In a rotameter, the flow area available for fluid passage varies with the float height:

A. Inversely

B. Logarithmically

C. Quadratically

D. Linearly

Q39. The Mach number is defined as the ratio of fluid velocity to the:

A. Speed of light

B. Terminal settling velocity

C. Speed of sound in the fluid

D. Average molecular velocity

Q40. The pressure loss head due to a sudden expansion from a pipe of velocity v_1 to a larger pipe of velocity v_2 is:

A. $(v_1^2 - v_2^2)/2g$

B. $(v_1 - v_2)^2/2g$

C. $(v_1 + v_2)^2/2g$

D. $(v_1^2 + v_2^2)/2g$

Q41. The hydraulic diameter of a square duct with side length a is:

A. $a/2$

B. a

C. $2a$

D. $4a$

Q42. Thermal diffusivity (α) characterizes how fast heat diffuses through a material and is defined as:

A. $\rho C_p/k$

B. $k/(\rho C_p)$

C. hL/k

D. $\mu C_p/k$

Q43. Fin effectiveness is defined as the ratio of the:

A. Heat transfer with the fin to that without the fin

B. Fin surface area to the base area

C. Convective resistance to conductive resistance

D. Actual heat transfer to maximum possible heat transfer

Q44. In natural convection heat transfer, the product of the Grashof number and the Prandtl number is called the:

A. Nusselt number

B. Peclet number

C. Rayleigh number

D. Stanton number

Q45. The view factor (shape factor) from the flat circular base of a hemisphere to its curved dome surface is:

A. 0.5

B. 1.0

C. 0.707

D. Determined by emissivity

Q46. On a typical pool boiling curve, the regime where the heat flux reaches its absolute local maximum is called the:

A. Film boiling regime

B. Critical heat flux (Burnout point)

C. Leidenfrost point

D. Natural convection regime

Q47. The logarithmic mean area used for calculating radial conductive heat transfer through a thick-walled cylinder is:

A. $(A_2 - A_1)/\ln(A_2/A_1)$

B. $(A_2 + A_1)/2$

C. $\sqrt{A_1 A_2}$

D. $(A_2 - A_1)/\ln(A_1/A_2)$

Q48. The Lewis number is a dimensionless parameter defined as the ratio of:

A. Kinematic viscosity to thermal diffusivity

B. Thermal diffusivity to mass diffusivity

C. Momentum diffusivity to mass diffusivity

D. Convective to conductive heat transfer

Q49. According to Higbie's Penetration Theory, the liquid-phase mass transfer coefficient k_L is proportional to contact time t as:

A. t

B. $t^{0.5}$

C. $t^{-0.5}$

D. t^{-1}

Q50. In a gas absorption column, operating at the minimum liquid-to-gas ratio mathematically corresponds to an absorber with:

A. Zero height

B. Infinite height

C. Maximum cross-sectional area

D. Zero pressure drop

Q51. Azeotropic distillation is utilized to separate the ethanol-water azeotrope by introducing an entrainer, commonly:

A. Toluene

B. Methanol

C. Benzene

D. Acetone

Q52. At the azeotropic point of a binary mixture, the relative volatility α is strictly:

A. Infinity

B. Zero

C. 1.0

D. Negative

Q53. Weeping in a tray distillation column is primarily caused by:

A. Excessively high vapor velocity

B. Excessively high liquid flow

C. Too low a vapor velocity

D. High condenser duty

Q54. In chemical reaction engineering, the space velocity of a reactor is the exact reciprocal of its:

A. Residence time distribution

B. Conversion factor

C. Space time (τ)

D. Reaction rate

Q55. Connecting a large number of identically sized CSTRs in series causes their overall residence time distribution to approach that of a:

A. Batch reactor

B. Single large CSTR

C. Plug Flow Reactor (PFR)

D. Fluidized bed reactor

Q56. The Maximum Mixedness Model is used to predict conversion in non-ideal reactors specifically for reactions with:

A. Linear first-order kinetics

B. Non-linear kinetics

C. Zero-order kinetics

D. Infinite rates

Q57. Catalyst deactivation due to sintering is primarily a physical process strongly accelerated by:

A. High pressure

B. High temperature

C. Presence of poisons

D. High reactant concentration

Q58. For an endothermic reversible reaction, increasing the operating temperature will:

A. Decrease the equilibrium conversion

B. Increase the equilibrium conversion

C. Leave equilibrium conversion unaffected

D. Stop the reaction entirely

Q59. For a first-order catalytic reaction within a porous pellet of length L, the Thiele modulus is proportional to:

A. $L\sqrt{k/D_e}$

B. $L\sqrt{D_e/k}$

C. $L(k/D_e)$

D. $(k/D_e)^2$

Q60. In the dispersion model for non-ideal flow, the vessel dispersion number for an ideal Plug Flow Reactor is exactly:

A. Infinity

B. 1

C. 0

D. -1

Q61. In process control, the frequency response phase lag for a pure dead time (transport delay) system $e^{-\tau_d s}$ at frequency ω is:

A. $-\tau_d/\omega$

B. $-\tau_d\omega$

C. $\tau_d\omega$

D. Zero

Q62. A control system possessing the closed-loop transfer function $G(s) = 1/(s^2 - 1)$ is inherently:

A. Critically damped

B. Overdamped

C. Stable

D. Unstable

Q63. In controller tuning, the Ziegler-Nichols quarter decay ratio criterion dictates that the amplitude of the second overshoot is:

A. Half of the first overshoot

B. One-quarter of the first overshoot

C. Equal to the first overshoot

D. Zero

Q64. A control strategy where a single controller output signal is used to sequentially operate two or more final control elements (valves) is called:

A. Cascade control

B. Ratio control

C. Split-range control

D. Feedforward control

Q65. Applying the Routh-Hurwitz criterion to the characteristic equation $s^3 + 2s^2 + s + 2 = 0$ reveals that the system is:

A. Stable

B. Unstable

C. Marginally stable (oscillatory)

D. Critically damped

Q66. The Laplace transform of the ideal unit impulse function (Dirac Delta function) $\delta(t)$ is:

A. 0

B. 1

C. $1/s$

D. s

Q67. In mechanical operations, Kick's law of size reduction is primarily applicable and accurate for:

A. Ultrafine grinding

B. Fine grinding

C. Coarse crushing

D. Colloid milling

Q68. Bond's Work Index is formally defined as the specific energy required to reduce particles from an infinite feed size down to a product size where 80% passes through:

A. 1 mm

B. 100 microns

C. 50 microns

D. 10 microns

Q69. To ensure cascading action rather than centrifuging, the optimum operating speed of a rotary ball mill is typically set at:

A. 10-20% of critical speed

B. 50-75% of critical speed

C. 100% of critical speed

D. 125% of critical speed

Q70. In cake filtration, a filter aid (like diatomaceous earth) is deliberately added to the slurry primarily to:

A. Decrease the cake porosity

B. Decrease the specific cake resistance

C. Increase the filtrate viscosity

D. React chemically with the solid

Q71. In Newton's regime (turbulent settling), the terminal settling velocity of a spherical particle is proportional to its diameter (D_p) raised to the power of:

A. 1

B. 2

C. 0.5

D. -1

Q72. In standard screen analysis, the "mesh number" explicitly indicates the number of square openings per:

A. Square inch

B. Square centimeter

C. Linear inch

D. Linear foot

Q73. In engineering economics, the "capitalized cost" of an asset is defined as its original cost plus the present value of:

A. Its annual depreciation

B. Its salvage value

C. Infinite perpetual renewals

D. Its working capital

Q74. The financial liquidity metric known as the "current ratio" is calculated as:

A. Current assets / Current liabilities

B. Current liabilities / Current assets

C. Fixed capital / Working capital

D. Net profit / Total assets

Q75. The estimated market value of an industrial asset at the exact end of its useful lifespan is called its:

A. Book value

B. Replacement value

C. Salvage value

D. Present value

Q76. Which depreciation method mathematically prevents the book value of an asset from ever reaching exactly zero?

A. Straight line method

B. Declining balance method

C. Sum-of-the-years-digits method

D. Sinking fund method

Q77. The simple payback period of an industrial project is roughly calculated as the fixed capital investment divided by:

A. Net annual profit

B. Annual sales revenue

C. Net annual profit + Annual depreciation

D. Total annual operating cost

Q78. In chemical technology, the industrial "Water Gas" is a combustible mixture consisting fundamentally of:

A. Carbon dioxide and water vapor

B. Carbon monoxide and hydrogen

C. Methane and oxygen

D. Nitrogen and hydrogen

Q79. In the modern Contact Process for producing sulfuric acid, the preferred catalyst for oxidizing SO_2 to SO_3 is:

A. Iron oxide

B. Platinum

C. Vanadium pentoxide

D. Nickel

Q80. The synthetic polymer Nylon 6 is manufactured via the ring-opening polymerization of a single monomer known as:

A. Adipic acid

B. Hexamethylenediamine

C. Caprolactam

D. Ethylene glycol

Q81. In the petroleum industry, the standard reference fuel assigned an octane number of exactly 0 is:

A. Iso-octane

B. n-Heptane

C. Benzene

D. Methane

Q82. The low-pressure industrial polymerization of ethylene into High-Density Polyethylene (HDPE) heavily relies on which catalyst?

A. Raney Nickel

B. Zeolite ZSM-5

C. Ziegler-Natta catalyst

D. Silica-Alumina

Q83. Viscose rayon, a manufactured semi-synthetic fiber, is chemically regenerated from naturally occurring:

A. Proteins

B. Cellulose

C. Starch

D. Lipids

Q84. The saponification value of a fat or oil is an analytical index used to indicate the:

A. Degree of unsaturation

B. Average molecular weight of the fatty acids

C. Amount of free iodine

D. Moisture content

Q85. The "economic pipe diameter" is the specific pipe size that perfectly minimizes the sum of the annualized pipe cost and the:

A. Insulation cost

B. Friction factor

C. Pumping power cost

D. Valve maintenance cost

Q86. The Height Equivalent to a Theoretical Plate (HETP) relates the separation performance of a packed column directly to that of a:

A. Continuous stirred tank

B. Staged tray column

C. Membrane separator

D. Liquid-liquid extractor

Q87. In condenser design, dropwise condensation is vastly preferred over filmwise condensation because it provides:

A. Easier condensate recovery

B. Higher heat transfer coefficients

C. Lower pressure drop

D. Better vapor purity

Q88. To maximize overall conversion for an autocatalytic reaction, the optimal reactor arrangement is a:

A. PFR followed by a CSTR

B. CSTR followed by a PFR

C. Single large PFR

D. Single large Batch reactor

Q89. Triple superphosphate fertilizer is manufactured by directly treating phosphate rock with:

A. Sulfuric acid

B. Nitric acid

C. Ammonia

D. Phosphoric acid

Q90. The Profitability Index (PI) of an investment project is formally calculated as the ratio of the present value of future cash flows to the:

A. Discount rate

B. Internal rate of return

C. Initial capital investment

D. Salvage value

Solutions

1. B
Explanation: Expanding $\tan x \approx x + x^3/3 + \ldots$, the numerator becomes $(x + x^3/3 - x) = x^3/3$. Dividing by x^3 and taking the limit yields $1/3$.

2. A
Explanation: The eigenvalue equation for $A^2 = A$ implies that the eigenvalues λ must satisfy $\lambda^2 = \lambda$, which factors to $\lambda(\lambda - 1) = 0$, meaning λ can only be 0 or 1.

3. C
Explanation: By mathematical definition, an orthogonal matrix Q has columns that are orthonormal vectors, resulting in the fundamental property $Q^TQ = I$, meaning $Q^{-1} = Q^T$.

4. B
Explanation: The gradient $\nabla\phi = (2xy + z, x^2, x)$ at $(1, 2, -1)$ is $(3, 1, 1)$. The unit directional vector is $(2/3, -2/3, 1/3)$. The dot product $(3)(2/3) + (1)(-2/3) + (1)(1/3) = 5/3$.

5. B
Explanation: The inner integral w.r.t y is $[xe^{y/x}]_0^x = x(e - 1)$. The outer integral w.r.t x is $\int_0^1 x(e - 1)dx = (e - 1)[x^2/2]_0^1 = \frac{1}{2}(e - 1)$.

6. C
Explanation: The pole $z = \pi i$ lies strictly inside the circle $|z| = 4$. By Cauchy's formula, $\oint \frac{f(z)}{z-a}dz = 2\pi i f(a)$. Here $f(\pi i) = e^{\pi i} = -1$, yielding $-2\pi i$.

7. C
Explanation: The characteristic equation $r^2 - 2r + 1 = 0$ yields a repeated root $r = 1$. For repeated roots, the general solution requires multiplying by x, giving $(c_1 + c_2x)e^x$.

8. B
Explanation: By definition, $L\{t^n\} = \int_0^\infty t^n e^{-st}dt$. Repeated integration by parts evaluated from 0 to ∞ yields exactly $n!/s^{n+1}$ for positive integers.

9. B
Explanation: The Trapezoidal rule fits a linear approximation across intervals. Its global truncation error scales proportionally to the square of the step size, h^2.

10. B
Explanation: Out of 36 total outcomes, the combinations yielding 8 are (2,6), (3,5), (4,4), (5,3), and (6,2). 5 combinations out of 36 gives a probability of 5/36.

11. B
Explanation: The curl of a gradient field $(\nabla \times (\nabla\phi))$ is mathematically identically zero because mixed partial derivatives of a smooth scalar function are equal and cancel out.

12. A
Explanation: Substituting $y = x^r$ into the Euler-Cauchy equation yields $r(r - 1) - 2r + 2 = 0 \implies r^2 - 3r + 2 = 0$. The roots are 1 and 2, giving $y = c_1x + c_2x^2$.

13. D

Explanation: The function $1/(z^2+1)$ factors to $1/((z-i)(z+i))$. The residue at the simple pole $z=i$ is found by evaluating $1/(z+i)$ at $z=i$, giving $1/2i = -i/2$.

14. B
Explanation: For a continuous uniform distribution perfectly spread between boundaries a and b, the expected value (mean) is precisely the arithmetic midpoint, $(a+b)/2$.

15. A
Explanation: Setting the first derivative $f'(x) = e^{-x} - xe^{-x} = e^{-x}(1-x)$ to zero yields $x=1$. The second derivative is negative at $x=1$, confirming a maximum.

16. C
Explanation: Let $f(x) = x^3 - x - 1$. Evaluating at boundaries: $f(1) = 1-1-1 = -1$ (negative) and $f(2) = 8-2-1 = 5$ (positive). By IVT, a root strictly exists between 1 and 2.

17. B
Explanation: The Rank-Nullity Theorem states that for any $m \times n$ matrix, the rank (dimension of column space) plus the nullity (dimension of null space) precisely equals the number of columns, n.

18. C
Explanation: For the linear ODE $y' + p(x)y = q(x)$, the integrating factor is $e^{\int p(x)dx}$. Since $p(x) = 1$, the integral is x, making the integrating factor e^x.

19. C
Explanation: The integral definition of $\Gamma(1/2) = \int_0^\infty x^{-1/2}e^{-x}dx$. With a substitution $x = u^2$, it reduces to the Gaussian integral, which evaluates exactly to $\sqrt{\pi}$.

20. D
Explanation: The conditional probability $P(A|B)$ formalizes the probability of A occurring given that B has occurred, defined exactly as the joint probability $P(A \cap B)$ divided by $P(B)$.

21. C
Explanation: The series elegantly alternates between cubes and squares of natural numbers: $1^3, 2^2, 3^3, 4^2, 5^3, 6^2$. The 7th term must be $7^3 = 343$.

22. A
Explanation: Since A's mother is B's sister, B and A's mother are siblings. C is the daughter of A's mother, making C the niece of B. Conversely, B is the uncle or aunt to C.

23. C
Explanation: The code strictly sums the standard alphabetical positions of the letters. CAT = 3+1+20 = 24. DOG = 4+15+7 = 26. Therefore, RAT = 18+1+20 = 39.

24. A
Explanation: The path is 10m North, 20m East (right), 10m South (right), then 10m East (left). The North and South movements completely cancel, leaving $20 + 10 = 30$ m East.

25. A

Explanation: A classic Venn diagram shows that if a part of A overlaps with B, and the entirety of B is contained within C, then that overlapping part of A must absolutely be inside C.

26. B
Explanation: A leap year has 366 days, which is exactly 52 weeks plus 2 extra consecutive days. There are 7 possible pairs for these 2 days, and exactly 2 of those pairs contain a Sunday.

27. A
Explanation: The formula for total queue length given positions from both ends is (Front Position + Back Position - 1). Therefore, $10 + 20 - 1 = 29$ people.

28. C
Explanation: Mercury, Venus, and Mars are independent primary planets orbiting the sun, whereas the Moon is merely a natural satellite orbiting a planet (Earth), making it the odd one out.

29. B
Explanation: For a round trip of identical distances at speeds v_1 and v_2, the harmonic mean defines the average speed: $2v_1v_2/(v_1 + v_2) = (2 \times 40 \times 60)/100 = 48$ km/hr.

30. A
Explanation: At 3:30, the minute hand is at 180° (on the 6). The hour hand has moved halfway past the 3, resting at $90° + 15° = 105°$. The strict difference is $180 - 105 = 75°$.

31. C
Explanation: Fugacity is the effective thermodynamic pressure. For liquids at low pressures where the vapor behaves ideally, the liquid's escaping tendency (fugacity) perfectly matches its equilibrium vapor pressure.

32. C
Explanation: A residual property measures the precise deviation of a real gas from ideal gas behavior. Since an ideal gas perfectly follows its own model, its residual volume $V - V_{ideal}$ is strictly 0.

33. B
Explanation: The exact Clapeyron equation is simplified into the Clausius-Clapeyron equation by assuming the specific volume of the liquid is negligibly small compared to the specific volume of the vapor.

34. C
Explanation: At the critical point, the intense thermodynamic state causes the liquid and vapor phases to become completely indistinguishable, reducing the enthalpy of vaporization (latent heat) exactly to zero.

35. B
Explanation: The COP of a refrigerator is defined as cooling effect over work input (Q_c/W). For an ideal Carnot cycle, replacing heats with absolute temperatures gives $T_c/(T_h - T_c)$.

36. A
Explanation: Newton's law of viscosity strictly defines a Newtonian fluid as one

where the internal shear stress (τ) is linearly and directly proportional to the local velocity gradient (du/dy).

37. B
Explanation: Flow separation from a wall occurs strictly when boundary layer momentum is overcome by an adverse pressure gradient (pressure increasing in the flow direction, $dp/dx > 0$), forcing flow reversal.

38. D
Explanation: A rotameter features a tapered tube design where the annular cross-sectional area available for upward fluid flow increases strictly linearly with the vertical displacement of the float.

39. C
Explanation: The Mach number is a fundamental dimensionless gas dynamic ratio comparing the local velocity of the fluid flow to the local thermodynamic speed of sound within that exact same fluid.

40. B
Explanation: The Borda-Carnot equation demonstrates that the permanent mechanical energy lost to violent turbulent eddies in a sudden pipe expansion is precisely calculated as $(v_1 - v_2)^2/2g$.

41. B
Explanation: The hydraulic diameter is defined as $4\times$(Cross-sectional Area)/(Wetted Perimeter). For a square duct of side a, this evaluates exactly to $4a^2/4a = a$.

42. B
Explanation: Thermal diffusivity α equals $k/(\rho C_p)$. It physically represents a material's ability to swiftly conduct thermal energy relative to its inherent ability to store that energy volumetrically.

43. A
Explanation: Fin effectiveness acts as a performance metric, strictly defined as the ratio of the enhanced heat transfer rate achieved with the fin attached to the baseline heat transfer rate of the bare surface.

44. C
Explanation: The Rayleigh number ($Ra = Gr \times Pr$) dictates the dominant heat transfer mechanism in natural convection, precisely indicating whether the convective flow is laminar or turbulent.

45. B
Explanation: Because a flat circular base is strictly planar, it views none of itself ($F_{11} = 0$). By the enclosure rule, 100% of the radiation leaving the flat base must strike the enclosing hemispherical dome ($F_{12} = 1.0$).

46. B
Explanation: The critical heat flux (CHF) marks the absolute peak of the nucleate boiling regime before continuous vapor films blanket the surface, drastically dropping heat transfer and spiking surface temperature.

47. A
Explanation: When analyzing 1D radial steady-state conduction through a cylindrical wall, integrating the expanding area yields a logarithmic mean area strictly

defined as $(A_2 - A_1)/\ln(A_2/A_1)$.

48. B
Explanation: The Lewis number ($Le = \alpha/D_{AB} = Sc/Pr$) is a dimensionless ratio that directly compares a fluid's thermal diffusivity to its mass diffusivity, crucial for simultaneous heat and mass transfer.

49. C
Explanation: Higbie's Penetration Theory mathematically models brief, unsteady-state molecular diffusion into surface fluid elements, predicting that the mass transfer coefficient strictly scales with $t^{-0.5}$.

50. B
Explanation: Operating exactly at the minimum liquid-to-gas ratio creates a thermodynamic pinch point where the driving force becomes zero. Achieving the desired separation at this ratio theoretically requires infinite column height.

51. C
Explanation: Benzene is historically the most common entrainer added to ethanol-water mixtures. It aggressively alters the activity coefficients, forming a low-boiling ternary azeotrope that allows pure ethanol recovery.

52. C
Explanation: An azeotrope represents an invariant state where the liquid and vapor phases possess identical compositions ($y = x$). Consequently, the relative volatility $\alpha = (y/x)_A/(y/x)_B$ mathematically equals 1.0.

53. C
Explanation: Weeping is a severe hydraulic failure in trayed columns that occurs when the upward vapor velocity is too low to support the liquid head, causing liquid to literally rain down through the tray perforations.

54. C
Explanation: Space velocity physically denotes the number of reactor volumes treated per unit time, making it the exact mathematical reciprocal of space time (τ), which is the time required to process one reactor volume.

55. C
Explanation: A single CSTR provides complete back-mixing. However, as numerous CSTRs are connected in series, the overall flow progressively loses back-mixing, ultimately converging perfectly into Plug Flow (PFR) behavior.

56. B
Explanation: For purely linear (first-order) kinetics, conversion depends solely on the RTD. For non-linear kinetics (order $\neq 1$), the exact degree of fluid micromixing matters, requiring models like Maximum Mixedness.

57. B
Explanation: Catalyst sintering is a thermally driven physical degradation process where microscopic active surface pores collapse and merge, causing severe loss of surface area when exposed to excessively high temperatures.

58. B
Explanation: According to Le Chatelier's principle, applying heat to an endothermic (heat-absorbing) reaction heavily shifts the thermodynamic equilibrium toward

the products, strictly increasing the overall conversion.

59. A
Explanation: The Thiele modulus is a dimensionless number comparing the surface reaction rate to the internal pore diffusion rate. For first-order reactions in a porous pellet of length L, it scales exactly as $L\sqrt{k/D_e}$.

60. C
Explanation: The vessel dispersion number (D/uL) measures axial mixing. An ideal Plug Flow Reactor perfectly eliminates all axial mixing, rendering its formal dispersion number exactly zero.

61. B
Explanation: In the frequency domain ($s = i\omega$), a pure transport delay $e^{-\tau_d s}$ becomes $e^{-i\tau_d \omega}$. By Euler's formula, the magnitude is 1, and the phase angle lag is strictly proportional to frequency, given by $-\tau_d \omega$.

62. D
Explanation: The characteristic equation $s^2 - 1 = 0$ yields roots at $s = +1$ and $s = -1$. Because there is a strict pole located in the positive right-half of the complex plane, the system is fundamentally unstable.

63. B
Explanation: The Ziegler-Nichols tuning heuristic aims to achieve a highly responsive yet rapidly settling system by ensuring that each successive oscillation amplitude decays to exactly one-quarter (25%) of the previous peak.

64. C
Explanation: Split-range control is a specialized architecture where a single controller strictly sequences multiple valves—for example, one valve opens from 0-50% signal, and the second opens from 50-100% signal.

65. B
Explanation: Constructing the Routh array gives row 1: (1, 1), row 2: (2, 2). Row 3 evaluates to $(2 \times 1 - 1 \times 2)/2 = 0$. A leading zero indicates roots on the imaginary axis or right-half plane, confirming instability.

66. B
Explanation: The Dirac Delta function $\delta(t)$ represents an infinitely tall, infinitely narrow spike with an exact area of 1. Integrating $\int_0^\infty \delta(t)e^{-st}dt$ cleanly samples the exponential at $t = 0$, yielding exactly 1.

67. C
Explanation: Kick's law assumes the energy required is proportional only to the volumetric ratio of size reduction (D_f/D_p). It remains empirically accurate predominantly for large-scale, coarse crushing operations.

68. B
Explanation: Bond's Work Index is an empirical standard rigorously defined as the gross energy requirement (in kWh/ton) to mill infinitely large feed particles down to a product where exactly 80% passes a 100-micron screen.

69. B
Explanation: To maximize grinding efficiency, the mill must spin fast enough to lift the balls but slowly enough to prevent them from centrifuging to the wall. This

cascading optimum is strictly 50-75% of the critical speed.

70. B
Explanation: Fine, highly compressible slurries quickly blind filter cloths. Adding rigid, porous filter aids strictly increases cake permeability, profoundly decreasing the specific cake resistance and improving flux.

71. C
Explanation: In Newton's regime (turbulent drag), the drag coefficient is constant. Equating gravity and drag forces reveals that the terminal settling velocity strictly scales with the square root of the particle diameter ($D_p^{0.5}$).

72. C
Explanation: By exact industrial definition, the standard "mesh number" explicitly denotes the total number of square sieve openings per linear inch across the screen surface.

73. C
Explanation: Capitalized cost evaluates assets with extremely long or perpetual service lives. It strictly equals the original investment plus the present value of the cash required to perpetually renew the asset forever.

74. A
Explanation: The current ratio is a strict balance sheet metric evaluating short-term liquidity, mathematically calculated by dividing the company's total current assets strictly by its total current liabilities.

75. C
Explanation: The salvage value (or scrap value) strictly represents the estimated, residual net market value that an industrial asset can be sold for at the precise end of its designated depreciable lifespan.

76. B
Explanation: The declining balance method deducts a constant percentage from the remaining book value every year. Because it is a continuous fractional reduction, the theoretical book value asymptotically approaches, but never reaches, zero.

77. C
Explanation: The simple payback period estimates capital recovery time. It is strictly calculated by dividing the initial fixed capital investment by the total annual cash flow (which is net profit plus depreciation).

78. B
Explanation: Industrial Water Gas, historically generated by passing steam over incandescent coke, is a highly flammable synthesis gas composed strictly of a roughly equimolar mixture of Carbon Monoxide and Hydrogen.

79. C
Explanation: While platinum was historically utilized, modern Contact Process plants universally rely on Vanadium pentoxide (V_2O_5) because it strongly resists heavy metal poisoning while maintaining excellent high-temperature oxidation activity.

80. C
Explanation: Unlike Nylon 6,6 which uses two monomers, Nylon 6 is manufac-

tured strictly via the heat-driven, ring-opening chain-growth polymerization of a single 6-carbon cyclic amide called Caprolactam.

81. B
Explanation: The octane rating scale is strictly calibrated against two reference fuels: highly knock-resistant Iso-octane is defined exactly as 100, while highly knock-prone n-Heptane is defined exactly as 0.

82. C
Explanation: Ziegler-Natta catalysts are unique, stereospecific transition-metal organometallic complexes that exclusively allow the continuous polymerization of ethylene into rigid, unbranched High-Density Polyethylene at strict low pressures.

83. B
Explanation: Viscose rayon is not fully synthetic; it is strictly a regenerated fiber created by chemically dissolving heavily purified natural wood cellulose into a viscous solution, then extruding it back into solid cellulose filaments.

84. B
Explanation: The saponification value measures the strict mass of potassium hydroxide required to saponify 1 gram of fat, providing an exact inverse indication of the average molecular weight (chain length) of the constituent fatty acids.

85. C
Explanation: The economic pipe diameter strictly balances capital and operating expenses, finding the precise diameter where the high annualized cost of large piping intersects the high continuous electrical cost of pumping through small piping.

86. B
Explanation: The Height Equivalent to a Theoretical Plate (HETP) is a strict bridging parameter that allows engineers to size continuous packed columns by converting their performance into equivalent discrete equilibrium stages (trays).

87. B
Explanation: Film condensation creates a continuous, thermally insulating liquid layer. Dropwise condensation strictly leaves large areas of the cold surface exposed, drastically increasing the overall heat transfer coefficients by orders of magnitude.

88. B
Explanation: Autocatalytic reactions start incredibly slow but accelerate. The strict optimal design utilizes a CSTR to instantly jump the feed to a high-reaction-rate composition, followed by a PFR to drive the final high-conversion tail.

89. D
Explanation: Treating phosphate rock strictly with sulfuric acid yields low-grade single superphosphate (containing gypsum). Treating the rock strictly with phosphoric acid yields highly concentrated, gypsum-free triple superphosphate.

90. C
Explanation: The Profitability Index (PI), also known as the value investment ratio, is strictly calculated by dividing the total present discounted value of all future expected cash flows by the initial capital investment outlay.