# PRACTICE EXAM 10: FE CHEMICAL SIMULATION (110 QUESTIONS)

**Mathematics**

1. What is the general solution of the differential equation $y'' - y = 0$?

A. $y = C_1\cos(x) + C_2\sin(x)$

B. $y = C_1e^x + C_2e^{(-x)}$

C. $y = (C_1 + C_2x)e^x$

D. $y = C_1e^{(2x)} + C_2e^{(-2x)}$

2. Evaluate the definite integral of 2x from x = 0 to x = 3.

A. 6

B. 9

C. 3

D. 18

3. A square matrix is singular when its determinant is:

A. Zero

B. One

C. Positive

D. Equal to its trace

4. What is the magnitude of the vector (3, 4)?

A. 7

B. 12

C. 5

D. 25

5. What is the derivative of tan(x) with respect to x?

A. $\sec^2(x)$

B. $-\csc^2(x)$

C. cos(x)

D. sec(x)tan(x)

6. What is the Laplace transform of the constant function f(t) = 1?

A. s

B. 1

C. $1/s^2$

D. 1/s

**Probability and Statistics**

7. Given P(B) = 0.4 and P(A | B) = 0.5, what is the joint probability $P(A \cap B)$?

A. 0.9

B. 0.5

C. 0.4

D. 0.20

8. What is the mode of the data set 2, 3, 3, 3, 5, and 8?

A. 3

B. 4

C. 8

D. 5

9. In how many ways can 3 items be chosen from a set of 7 distinct items, where order does not matter?

A. 35

B. 21

C. 210

D. 343

10. Approximately what fraction of normally distributed data lies within one standard deviation of the mean?

A. About 95%

B. About 68%

C. About 99.7%

D. About 34%

11. A binomial process has 100 trials with a success probability of 0.5. What is the variance?

A. 50

B. 100

C. 25

D. 5

**Engineering Sciences**

12. A constant force of 80 N moves an object 5 m in the direction of the force. How much work is done?

A. 16 J

B. 400 J

C. 85 J

D. 75 J

13. Two 10 Ω resistors are connected in parallel. What is the equivalent resistance?

A. 20 Ω

B. 5 Ω

C. 10 Ω

D. 100 Ω

14. A 2 kg object changes its velocity by 5 m/s. What is the impulse delivered to it?

A. 10 kg·m/s

B. 2.5 kg·m/s

C. 7 kg·m/s

D. 0.4 kg·m/s

15. A machine performs 600 J of work in 3 seconds. What is its power output?

A. 1800 W

B. 0.005 W

C. 200 W

D. 603 W

**Materials Science**

16. The Rockwell test is used to measure a material's:

A. Toughness

B. Hardness

C. Ductility

D. Conductivity

17. A sharp notch in a loaded component produces:

A. A uniform reduction in stress

B. A lower fatigue risk

C. Increased local ductility

D. A local stress concentration

18. Which iron–carbon phase is soft and ductile at room temperature?

A. Martensite

B. Cementite

C. Austenite

D. Ferrite

19. Galvanising protects steel by coating it with a layer of:

A. Copper

B. Zinc

C. Tin

D. Paint alone

20. Compared with steel, aluminium has:

A. A lower elastic modulus

B. A higher elastic modulus

C. An identical elastic modulus

D. An effectively infinite modulus

**Chemistry and Biology**

21. What is the oxidation state of nitrogen in ammonia, $NH_3$?

A. +3

B. 0

C. −3

D. +5

22. What is the molar mass of sodium hydroxide, NaOH?

A. 23 g/mol

B. 40 g/mol

C. 56 g/mol

D. 24 g/mol

23. A fixed quantity of gas at 2 atm and 300 K is heated to 600 K at constant volume. What is the new pressure?

A. 1 atm

B. 2 atm

C. 4 atm

D. 8 atm

24. Adding more reactant to a system at equilibrium shifts the equilibrium toward:

A. The reactants

B. No net shift

C. The products

D. The solid phase

25. For A + B → AB, a reactor contains 5 mol of A and 8 mol of B. How many moles of AB can form?

A. 8 mol

B. 13 mol

C. 3 mol

D. 5 mol

26. An aqueous solution has a hydrogen ion concentration of $1 \times 10^{-5}$ mol/L. What is its pH?

A. 5

B. 9

C. $1 \times 10^{-5}$

D. 7

27. Breaking a chemical bond:

A. Releases energy

B. Involves no energy change

C. Requires an input of energy

D. Lowers the temperature spontaneously

28. Within a living cell, ATP functions chiefly as the:

A. Principal structural protein

B. Cell's energy currency

C. Genetic template

D. Main digestive enzyme

**Fluid Mechanics**

29. A fluid (density 1000 $kg/m^3$, viscosity 0.01 Pa·s) flows at 1 m/s through a 0.1 m pipe. What is the Reynolds number?

A. 10000

B. 1000

C. 100

D. 100000

30. Incompressible flow passes into a section of half the area. If the upstream velocity is 3 m/s, what is the downstream velocity?

A. 1.5 m/s

B. 3 m/s

C. 6 m/s

D. 12 m/s

31. In a pipe carrying fluid at constant velocity to a higher elevation, what happens to the static pressure as elevation increases?

A. It increases

B. It stays constant

C. It doubles

D. It decreases

32. What is the hydrostatic pressure at a depth of 2 m in water (density 1000 $kg/m^3$)?

A. 2 kPa

B. 19.6 kPa

C. 196 kPa

D. 1.96 kPa

33. For laminar pipe flow at a Reynolds number of 200, what is the Darcy friction factor?

A. 0.032

B. 64

C. 0.32

D. 3.2

34. A pump delivers 0.03 $m^3/s$ of water against a head of 25 m. What is the ideal hydraulic power?

A. 7.36 kW

B. 0.74 kW

C. 73.6 kW

D. 736 W

35. A flow of 0.5 $m^3/s$ passes through a duct of cross-sectional area 0.25 $m^2$. What is the velocity?

A. 2 m/s

B. 0.125 m/s

C. 8 m/s

D. 0.5 m/s

36. Using the Darcy equation with $f = 0.025$, $L = 50$ m, $D = 0.05$ m, and $v = 2$ m/s, what is the head loss?

A. 2.55 m

B. 10.2 m

C. 5.10 m

D. 1.02 m

37. Pipe flow is generally considered fully turbulent above a Reynolds number of approximately:

A. 100

B. 4000

C. 2100

D. 100000

**Thermodynamics**

38. A Carnot engine operates between 750 K and 300 K. What is its maximum efficiency?

A. 40%

B. 25%

C. 50%

D. 60%

39. Three moles of an ideal gas ($C_p$ = 30 J/mol·K) are heated by 20 K at constant pressure. What is the enthalpy change?

A. 900 J

B. 1800 J

C. 3600 J

D. 600 J

40. A closed system increases its internal energy by 600 J while doing 400 J of work. How much heat was added?

A. 200 J

B. 600 J

C. 1000 J

D. 400 J

41. A reservoir at 450 K reversibly absorbs 900 J of heat. What is its entropy change?

A. 0.5 J/K

B. 405000 J/K

C. 1 J/K

D. 2 J/K

42. A Carnot heat pump operates between 280 K and 320 K. What is its heating coefficient of performance, $T_h/(T_h - T_c)$?

A. 8

B. 7

C. 0.125

D. 1.14

43. An equimolar liquid mixture of A (pure vapour pressure 200 kPa) and B (100 kPa) follows Raoult's law. What is the bubble-point pressure?

A. 100 kPa

B. 150 kPa

C. 200 kPa

D. 300 kPa

44. A compressibility factor greater than one indicates that:

A. Repulsive intermolecular forces dominate

B. Attractive intermolecular forces dominate

C. The gas behaves ideally

D. The temperature is very low

45. A reversible adiabatic process is also described as:

A. Isothermal

B. Isobaric

C. Isentropic

D. Isochoric

46. What is the standard heat of formation of an element in its standard state?

A. Zero

B. Positive

C. Negative

D. Infinite

**Material and Energy Balances**

47. A 1200 kg/h feed is split among three products of 400 kg/h, 500 kg/h, and a remainder. What is the third product's flow rate?

A. 700 kg/h

B. 900 kg/h

C. 100 kg/h

D. 300 kg/h

48. An evaporator concentrates 800 kg/h of a 10% solids feed to a 40% solids product. What is the product (concentrate) flow rate?

A. 600 kg/h

B. 80 kg/h

C. 200 kg/h

D. 320 kg/h

49. Complete combustion of propane follows $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$. How many moles of oxygen are needed for 2 mol of propane?

A. 5 mol

B. 8 mol

C. 10 mol

D. 16 mol

50. A 100 kg stream of 50% salt is mixed with a 100 kg stream of 10% salt. What is the salt content of the mixture?

A. 60%

B. 30%

C. 20%

D. 50%

51. A reactor is fed 400 mol of A, of which 160 mol leaves unreacted. What is the conversion?

A. 40%

B. 60%

C. 100%

D. 160 mol

52. A process recycles 750 mol/h and receives a fresh feed of 250 mol/h. What is the recycle ratio?

A. 0.33

B. 1.5

C. 1000

D. 3

53. How much heat is needed to raise 50 kg of water by 10 °C, with a specific heat of 4.18 kJ/kg·K?

A. 209 kJ

B. 418 kJ

C. 2090 kJ

D. 4180 kJ

54. A solid has a moisture content of 30% on a wet basis. What is the equivalent moisture content on a dry basis?

A. 30%

B. 42.9%

C. 70%

D. 23%

55. In the reaction 2A → B, 6 mol of A reacts completely. How many moles of B are formed?

A. 6 mol

B. 3 mol

C. 12 mol

D. 2 mol

56. A burner requires 5 mol of oxygen stoichiometrically but is supplied with 6 mol. What is the percentage excess oxygen?

A. 16.7%

B. 120%

C. 20%

D. 83%

57. An inert tie component simplifies a material balance because it:

A. Reacts completely within the unit

B. Acts as the limiting reactant

C. Is removed entirely by recycle

D. Passes through unchanged, linking inlet and outlet

**Heat Transfer**

58. A 0.1 m thick wall (k = 2 W/m·K, area 3 $m^2$) has a 60 °C temperature difference across it. What is the conductive heat rate?

A. 360 W

B. 720 W

C. 1800 W

D. 3600 W

59. A 5 $m^2$ surface transfers 3000 W by convection with a temperature difference of 30 °C. What is the convective heat-transfer coefficient?

A. 200 W/$m^2$·K

B. 100 W/$m^2$·K

C. 20 W/$m^2$·K

D. 50 W/$m^2$·K

60. If the absolute temperature of a radiating surface is quadrupled, by what factor does its emissive power increase?

A. 256×

B. 64×

C. 16×

D. 4×

61. In an exchanger where both terminal temperature differences equal 30 °C, what is the log-mean temperature difference?

A. 0 °C

B. 30 °C

C. 60 °C

D. 15 °C

62. Three wall layers have thermal resistances of 0.2, 0.3, and 0.5 K/W in series. What is the total resistance?

A. 0.1 K/W

B. 0.5 K/W

C. 0.33 K/W

D. 1.0 K/W

63. Two convective films of 150 and 300 $W/m^2 \cdot K$ act in series with negligible wall resistance. What is the overall coefficient U?

A. 225 $W/m^2 \cdot K$

B. 450 $W/m^2 \cdot K$

C. 100 $W/m^2 \cdot K$

D. 50 $W/m^2 \cdot K$

64. An exchanger has $U = 400\ W/m^2 \cdot K$, area 5 $m^2$, and a log-mean temperature difference of 30 °C. What is the heat duty?

A. 6 kW

B. 12 kW

C. 30 kW

D. 60 kW

65. Thermal conductivity is expressed in which units?

A. $W/m^2 \cdot K$

B. $W/m \cdot K$

C. $J/kg \cdot K$

D. W/K

66. What is the primary purpose of adding fins to a heat-transfer surface?

A. To raise the bulk fluid temperature

B. To increase the surface area for heat transfer

C. To reduce conduction through the base

D. To lower the surface emissivity

**Mass Transfer and Separation**

67. Molar diffusion flux is expressed in which units?

A. $mol/m^3$

B. m/s

C. $mol/(m^2 \cdot s)$

D. mol/s

68. For a relative volatility of 2, what vapour composition is in equilibrium with a liquid of mole fraction 0.5?

A. 0.50

B. 0.67

C. 0.75

D. 0.33

69. A feed entering a distillation column as a subcooled liquid has a q-value that is:

A. Greater than 1

B. Equal to 0

C. Equal to 0.5

D. Negative

70. A solute with a distribution coefficient of 3 is contacted once with an equal volume of solvent. What fraction transfers to the extract?

A. 0.50

B. 0.75

C. 0.33

D. 0.25

71. A dilute absorber removes 95% of a solute, so C_in/C_out = 20. What is the number of transfer units, NTU = ln(C_in/C_out)?

A. 0.95

B. 3.0

C. 20

D. 0.05

72. Gas absorption into a liquid solvent is generally:

A. Exothermic, releasing heat

B. Endothermic, absorbing heat

C. Athermal, with no heat effect

D. Always at constant temperature

73. A higher mass-transfer coefficient indicates:

A. Faster transfer for a given driving force

B. Slower transfer in all cases

C. A zero driving force

D. That equilibrium has been reached

74. A reverse-osmosis membrane rated at 99% salt rejection passes what fraction of the salt to the permeate?

A. 99% of the salt

B. 1% of the salt

C. All of the salt

D. None of the water

75. The Langmuir adsorption isotherm is based on the assumption that adsorption forms:

A. Multiple layers without limit

B. A continuous liquid film

C. No surface coverage at all

D. A single monolayer on the surface

**Solids Handling**

76. A 250 μm particle ($\Delta\rho = 1500$ kg/m³) settles in a fluid of viscosity $2 \times 10^{-3}$ Pa·s. What is its Stokes' law terminal velocity?

A. $1.3 \times 10^{-2}$ m/s

B. $5.1 \times 10^{-2}$ m/s

C. $8.5 \times 10^{-3}$ m/s

D. $2.55 \times 10^{-2}$ m/s

77. A sieve analysis is performed to determine a powder's:

A. Particle density

B. Particle size distribution

C. Moisture content

D. Surface charge

78. The reduction ratio of a crusher is defined as the ratio of:

A. Feed size to product size

B. Product size to feed size

C. Energy input to mass

D. Mass to volume

79. As the gas velocity is raised above the minimum fluidisation velocity in a bed, the result is:

A. Bubbling with little further rise in pressure drop

B. Complete collapse of the bed

C. A doubling of pressure drop at each step

D. A complete halt to particle motion

**Chemical Reaction Engineering**

80. A first-order reaction ($k = 0.4$ min$^{-1}$) starts at 4 mol/L. What is the concentration after 5 minutes, using $C = C_0e^{(-kt)}$?

A. 1.47 mol/L

B. 0.27 mol/L

C. 0.54 mol/L

D. 2.0 mol/L

81. A first-order reaction ($k = 0.3\ min^{-1}$) runs in a PFR with a space time of 8 minutes. What conversion is achieved, using $X = 1 - e^{(-k\tau)}$?

A. 0.50

B. 0.63

C. 0.86

D. 0.91

82. A zero-order reaction has k = 2.5 mol/L·min and an initial concentration of 10 mol/L. What is its half-life, $t_{1/2} = C_0/(2k)$?

A. 4 min

B. 2 min

C. 5 min

D. 1 min

83. A larger pre-exponential factor A in the Arrhenius equation produces a:

A. Higher rate constant

B. Lower rate constant

C. Lower activation energy

D. No change in rate

84. To improve the equilibrium conversion of a reversible exothermic reaction, the appropriate action is to:

A. Raise the temperature

B. Add a catalyst only

C. Raise the pressure of the liquids

D. Lower the temperature

85. If a reaction rate doubles when the reactant concentration is doubled, the reaction order with respect to that reactant is:

A. 1

B. 2

C. 0

D. 3

86. A catalyst that has been deactivated by coke deposits is most commonly regenerated by:

A. Cooling it rapidly

B. Adding more feed

C. Burning off the carbon deposits

D. Increasing the system pressure

**Engineering Economics**

87. What is the future worth of $12,000 invested for 5 years at 7% interest ($1.07^5 = 1.4026$)?

A. $13,200

B. $14,400

C. $15,000

D. $16,831

88. A vessel costs $500,000 at a capacity of 20 $m^3$. Using the six-tenths rule, estimate the cost of an 80 $m^3$ vessel.

A. $2,000,000

B. $500,000

C. $862,000

D. $1,149,000

89. A project requires $900,000 of capital and returns $300,000 per year. What is the simple payback period?

A. 2 yr

B. 4 yr

C. 3 yr

D. 6 yr

90. A project returns $4,000 at the end of each year for 8 years at 10% interest (P/A factor 5.3349). What is its present worth?

A. $21,340

B. $32,000

C. $4,000

D. $40,000

**Process Design**

91. Which engineering diagram lists the stream flows, compositions, and conditions used for the material and energy balance?

A. The P&ID

B. The block flow diagram

C. The process flow diagram

D. The plot plan

92. The economic optimum insulation thickness for a pipe minimises:

A. Only the insulation cost

B. Only the heat-loss cost

C. The insulation cost plus the heat-loss cost

D. The pipe diameter

93. Equipment that cost $60,000 at a cost index of 500 is re-estimated at a current index of 650. What is the updated cost?

A. $46,200

B. $78,000

C. $60,000

D. $90,000

94. For a very large heat duty between two clean fluids, the most common exchanger choice is a:

A. Single jacketed vessel

B. Electric immersion heater

C. Small plate heater

D. Shell-and-tube exchanger

95. Geometric similarity in scale-up requires the larger unit to have:

A. The same absolute size as the small unit

B. An entirely different shape

C. The same shape with proportionally scaled dimensions

D. No relation to the small unit

96. For handling dilute sulphuric acid at moderate temperature, a suitable construction approach is:

A. A corrosion-resistant polymer or rubber lining

B. Plain carbon steel

C. Untreated aluminium

D. Mild steel alone

97. Critical safety instrumentation is commonly installed using:

A. A single sensor only

B. No backup at all

C. Redundant voting arrangements

D. Manual reading only

**Process Control**

98. A controller that combines proportional, integral, and derivative action is known as a:

A. P controller

B. PI controller

C. On–off controller

D. PID controller

99. Steady-state offset in a proportional-only controller arises because:

A. The controller gain is infinite

B. Integral action is too strong

C. A non-zero error is required to drive the output

D. The sensor has failed

100. A Bourdon tube is an instrument used to measure:

A. Pressure

B. Temperature

C. Flow rate

D. Liquid level

101. A fail-open control valve on a cooling-water line moves to which position on loss of signal?

A. Fully closed

B. Half open

C. Its last held position

D. Fully open, to maintain cooling

**Safety, Health, and Environment**

102. A vapour–air mixture whose concentration lies between the lower and upper flammability limits is:

A. Ignitable

B. Too lean to ignite

C. Too rich to ignite

D. Chemically inert

103. The most reliable way to reduce a process risk is to:

A. Add personal protective equipment

B. Remove or reduce the hazard at its source

C. Post warning signs

D. Increase the inspection frequency alone

104. The TLV-TWA of a substance represents:

A. The lethal dose

B. The odour-detection threshold

C. An instantaneous peak limit only

D. The 8-hour time-weighted average exposure limit

105. Under the standard classification, a fire involving combustible metals such as magnesium is a:

A. Class A fire

B. Class B fire

C. Class D fire

D. Class C fire

106. During a major chemical release, the first priority is to:

A. Recover the lost product

B. Document the incident before acting

C. Continue normal operation

D. Protect people and evacuate the area

**Ethics and Professional Practice**

107. An engineer who falsifies test results to meet a project deadline is:

A. Acting within professional discretion

B. Making an acceptable shortcut

C. Following standard industry practice

D. Committing a serious ethics violation

108. When an employer pressures an engineer to overlook a genuine safety defect, the engineer should:

A. Uphold public safety and escalate the concern

B. Comply silently with the employer's wishes

C. Resign without reporting the defect

D. Ignore it if the risk appears small

109. Designing for the full life cycle of a product means accounting for impacts from:

A. Raw-material extraction through end-of-life disposal

B. Only the manufacturing stage

C. Only the operating phase

D. Only the initial design phase

110. Reproducing a patented process commercially without a licence constitutes:

A. Fair use

B. An acceptable practice

C. A protected trade secret

D. Patent infringement

## Practice Exam 10 — Answer Key and Explanations

**1. B** — The characteristic equation $r^2 - 1 = 0$ gives real roots $r = \pm 1$, so the solution is $y = C_1 e^x + C_2 e^{-x}$. Real, distinct roots produce exponential solutions, as in unstable or overdamped systems.

**2. B** — The antiderivative of $2x$ is $x^2$, evaluated from 0 to 3 as $9 - 0 = 9$. Definite integration accumulates a quantity over the interval.

**3. A** — A square matrix is singular, and therefore non-invertible, precisely when its determinant equals zero. A zero determinant signals dependent rows and no unique solution.

**4. C** — The magnitude is $\sqrt{3^2 + 4^2} = \sqrt{25} = 5$. This is the familiar 3-4-5 right-triangle relationship for vector length.

**5. A** — The derivative of $\tan(x)$ is $\sec^2(x)$. This identity is standard in differentiating trigonometric expressions that arise in oscillatory analysis.

**6. D** — The Laplace transform of the constant 1 is $1/s$. This basic pairing is the starting point for transforming step inputs in control analysis.

**7. D** — The joint probability is $P(B) \cdot P(A \mid B) = 0.4 \times 0.5 = 0.20$. Multiplying the marginal by the conditional gives the intersection probability.

**8. A** — The mode is the most frequently occurring value, which is 3 (appearing three times). The mode identifies the most common observation in a data set.

**9. A** — The number of combinations is $C(7,3) = 7!/(3!4!) = 35$. Combinations count unordered selections.

**10. B** — Approximately 68% of normally distributed data lies within one standard deviation of the mean, by the empirical rule. This benchmark sets common control and confidence limits.

**11. C** — Binomial variance is $np(1 - p) = 100 \times 0.5 \times 0.5 = 25$. Variance peaks at $p = 0.5$ for a given number of trials.

**12. B** — Work is force times distance, $80 \times 5 = 400$ J. This product gives the energy transferred when a force moves an object.

**13. B** — Two equal resistors in parallel give half the value, $10/2 = 5\ \Omega$. The parallel equivalent is always less than the smallest individual resistor.

**14. A** — Impulse equals the change in momentum, $m\Delta v = 2 \times 5 = 10$ kg·m/s. Impulse measures the effect of a force acting over time.

**15. C** — Power is work over time, 600/3 = 200 W. Power expresses the rate at which work is performed.

**16. B** — The Rockwell test measures hardness by the depth of penetration of an indenter under load. Hardness correlates with wear resistance and strength.

**17. D** — A sharp notch creates a local stress concentration, where stress rises well above the nominal value. These concentrations are frequent initiation sites for fatigue cracks.

**18. D** — Ferrite is the soft, ductile body-centred-cubic phase of iron stable at room temperature. Its ductility contrasts with the hard, brittle cementite and martensite phases.

**19. B** — Galvanising coats steel with zinc, which both forms a barrier and acts as a sacrificial anode. The zinc corrodes preferentially, protecting the underlying steel.

**20. A** — Aluminium has a lower elastic modulus than steel, roughly 70 GPa against 200 GPa, so it deflects more under the same load. This lower stiffness must be considered when substituting aluminium for steel.

**21. C** — Hydrogen carries +1 each, so three hydrogens give +3, and nitrogen must be −3 for a neutral molecule. Tracking oxidation states is essential for balancing redox reactions.

**22. B** — Summing atomic masses, Na (23) + O (16) + H (1) = 40 g/mol. Molar mass converts between mass and moles in stoichiometry.

**23. C** — At constant volume, pressure is proportional to absolute temperature, so $P_2 = 2 \times 600/300 = 4$ atm. Doubling the absolute temperature doubles the pressure.

**24. C** — Adding more reactant disturbs the equilibrium, and by Le Chatelier's principle the system shifts toward products to consume the excess. This shift increases product formation.

**25. D** — With 5 mol of A and 8 mol of B reacting one-to-one, A is limiting and yields 5 mol of AB. The limiting reactant caps the product formed.

**26. A** — pH is $-\log[H^+] = -\log(10^{-5}) = 5$. The logarithmic scale converts the small ion concentration into a convenient value.

**27. C** — Breaking a chemical bond requires an input of energy, since the bond holds the atoms together. Energy is released only when new bonds form.

**28. B** — ATP is the cell's energy currency, storing and delivering energy for cellular processes through its phosphate bonds. Its hydrolysis powers most energy-requiring reactions.

**29. A** — Reynolds number is $\rho vD/\mu = (1000 \times 1 \times 0.1)/0.01 = 10{,}000$. This turbulent value sets the appropriate friction correlation.

**30. C** — Continuity gives $v_2 = v_1A_1/A_2 = 3 \times 2 = 6$ m/s. Halving the area doubles the velocity, conserving volumetric flow.

**31. D** — Bernoulli's equation conserves total head, so at constant velocity a rise in elevation comes at the expense of static pressure, which decreases. The pressure energy is converted to elevation head.

**32. B** — Hydrostatic pressure is $\rho gh = 1000 \times 9.81 \times 2 = 19{,}620$ Pa $\approx 19.6$ kPa. Pressure rises linearly with depth.

**33. C** — For laminar flow, the friction factor is $64/Re = 64/200 = 0.32$. The strong inverse dependence on Reynolds number gives high friction at low flow.

**34. A** — Ideal hydraulic power is $\rho gQH = 1000 \times 9.81 \times 0.03 \times 25 = 7357.5$ W $\approx 7.36$ kW. Dividing by efficiency would give the shaft power required.

**35. A** — Velocity is flow rate over area, $0.5/0.25 = 2$ m/s. This relation follows directly from the continuity equation.

**36. C** — The Darcy equation gives $h_f = f(L/D)(v^2/2g) = 0.025 \times (50/0.05) \times (4/19.62) = 5.10$ m. Friction head loss scales with the square of velocity.

**37. B** — Pipe flow is generally fully turbulent above a Reynolds number of about 4000, with a transition region between roughly 2100 and 4000. This threshold determines which flow model applies.

**38. D** — Carnot efficiency is $1 - T_c/T_h = 1 - 300/750 = 0.60$, or 60%. The large temperature ratio raises the theoretical ceiling.

**39. B** — Enthalpy change at constant pressure is $nC_p\Delta T = 3 \times 30 \times 20 = 1800$ J. The constant-pressure heat capacity governs the heating duty.

**40. C** — The first law gives $Q = \Delta U + W = 600 + 400 = 1000$ J. Heat supplied both raises internal energy and does work.

**41. D** — Reservoir entropy change is $Q/T = 900/450 = 2$ J/K. This reversible-transfer expression underlies second-law analysis.

**42. A** — The heating coefficient of performance is $T_h/(T_h - T_c) = 320/40 = 8$. The small temperature lift gives a high COP.

**43. B** — Raoult's law gives the bubble pressure as $0.5 \times 200 + 0.5 \times 100 = 150$ kPa. The total pressure is the mole-fraction-weighted sum of the pure vapour pressures.

**44. A** — A compressibility factor above one indicates that repulsive intermolecular forces dominate, expanding the gas beyond its ideal volume. This is typical at very high pressure.

**45. C** — A reversible adiabatic process is termed isentropic, since its entropy remains constant. It provides the ideal benchmark for compressors and turbines.

**46. A** — The standard heat of formation of an element in its standard state is defined as zero, serving as the reference baseline. All compound formation enthalpies are measured relative to this datum.

**47. D** — A mass balance gives the third product as $1200 - 400 - 500 = 300$ kg/h. Conservation of mass closes the split.

**48. C** — A solids balance gives $0.10 \times 800 = 0.40 \times L$, so the concentrate product is $L = 200$ kg/h. The non-volatile solids fix the product rate.

**49. C** — At 5 mol of oxygen per mole of propane, 2 mol of propane requires $2 \times 5 = 10$ mol. Combustion stoichiometry sets the oxygen demand.

**50. B** — The combined salt is $0.50 \times 100 + 0.10 \times 100 = 60$ kg in 200 kg, giving 30%. A component balance yields the blended composition.

**51. B** — Conversion is $(400 - 160)/400 = 60\%$. This fraction measures how completely the feed is consumed.

**52. D** — The recycle ratio is recycle over fresh feed, $750/250 = 3$. It characterises the process's reliance on recycling.

**53. C** — Sensible heat is $mC_p\Delta T = 50 \times 4.18 \times 10 = 2090$ kJ. This relation sizes the heating duty for a temperature change without phase change.

**54. B** — Converting 30% wet basis gives dry basis $= 30/(100 - 30) = 42.9\%$. The dry basis is always the larger figure.

**55. B** — The stoichiometry consumes two moles of A per mole of B, so 6 mol of A yields 3 mol of B. Reaction stoichiometry converts reactant consumed into product formed.

**56. C** — Percentage excess is $(6 - 5)/5 = 20\%$. The surplus oxygen ensures complete combustion and passes through unreacted.

**57. D** — A tie component passes through a unit unchanged, linking the inlet and outlet flows and simplifying the balance. Its constant amount provides a reference for the other streams.

**58. D** — Fourier's law gives $Q = kA\Delta T/L = (2 \times 3 \times 60)/0.1 = 3600$ W. Conductive heat rate scales with conductivity, area, and driving temperature.

**59. C** — Rearranging $Q = hA\Delta T$ gives $h = 3000/(5 \times 30) = 20$ W/m²·K. The coefficient measures how effectively the fluid removes heat.

**60. A** — Emissive power scales with the fourth power of absolute temperature, so quadrupling T raises it by $4^4 = 256$ times. This steep dependence makes radiation dominate at high temperatures.

**61. B** — With both terminal differences equal at 30 °C, the log-mean reduces to that common value, 30 °C. The LMTD departs from the arithmetic mean only when the end differences differ.

**62. D** — Series resistances add directly, 0.2 + 0.3 + 0.5 = 1.0 K/W. The thermal-circuit analogy makes composite-wall problems straightforward.

**63. C** — With negligible wall resistance, 1/U = 1/150 + 1/300 = 0.01, so U = 100 $W/m^2 \cdot K$. The overall coefficient is smaller than either film coefficient.

**64. D** — Exchanger duty is $UA\Delta T = 400 \times 5 \times 30 = 60{,}000$ W = 60 kW. This product of coefficient, area, and driving force sizes the exchanger.

**65. B** — Thermal conductivity is expressed in watts per metre-kelvin (W/m·K). These units follow from Fourier's law of conduction.

**66. B** — Fins increase the surface area available for convection, which is their primary purpose. The added area boosts the heat transferred for a given coefficient and temperature difference.

**67. C** — Molar diffusion flux is moles transferred per unit area per unit time, with units of $mol/(m^2 \cdot s)$. These units follow directly from Fick's law.

**68. B** — Using $y = \alpha x/[1 + (\alpha - 1)x] = (2 \times 0.5)/(1 + 0.5) = 1.0/1.5 = 0.67$. The vapour is enriched in the volatile component relative to the liquid.

**69. A** — A subcooled liquid feed has a q-value greater than one, because more than the full latent heat must be supplied to vaporise it. The q-value sets the slope of the feed line on a McCabe–Thiele diagram.

**70. B** — For equal volumes, the fraction extracted is K/(K + 1) = 3/4 = 0.75. A higher distribution coefficient drives more solute into the extract.

**71. B** — The number of transfer units is ln(C_in/C_out) = ln(20) ≈ 3.0. NTU rises with the fractional removal demanded.

**72. A** — Gas absorption is generally exothermic, releasing the heat of solution as the gas dissolves. This heat release can raise the liquid temperature and reduce solubility in tall absorbers.

**73. A** — A higher mass-transfer coefficient means faster transfer for a given concentration driving force. It reflects more vigorous mixing or a thinner boundary film at the interface.

**74. B** — A 99% rejection membrane allows 1% of the salt to pass into the permeate, retaining the remainder. The rejection figure directly gives the fraction excluded.

**75. D** — The Langmuir isotherm assumes adsorption forms a single monolayer of molecules on uniform surface sites. This monolayer assumption gives its characteristic saturating shape.

**76. D** — Stokes' law gives $v = gd^2\Delta\rho/(18\mu) = (9.81 \times (2.5 \times 10^{-4})^2 \times 1500)/(18 \times 2 \times 10^{-3}) = 2.55 \times 10^{-2}$ m/s. The square dependence on diameter makes settling velocity highly size-sensitive.

**77. B** — A sieve analysis sorts a sample through a stack of screens to determine its particle size distribution. This distribution governs flow, packing, and processing behaviour.

**78. A** — The reduction ratio is the ratio of feed size to product size, measuring how much a crusher reduces the material. A larger ratio indicates more aggressive size reduction.

**79. A** — Raising the gas velocity above minimum fluidisation produces bubbling, while the bed pressure drop stays roughly constant at the bed weight. The extra gas passes through as bubbles, enhancing mixing.

**80. C** — First-order decay gives $C = C_0 e^{(-kt)} = 4 \times e^{(-0.4 \times 5)} = 4 \times e^{(-2)} = 4 \times 0.135 = 0.54$ mol/L. The concentration falls exponentially at a rate fixed by k.

**81. D** — For a first-order PFR, conversion is $X = 1 - e^{(-k\tau)} = 1 - e^{(-0.3 \times 8)} = 1 - e^{(-2.4)} = 1 - 0.091 = 0.91$. The plug-flow reactor reaches high conversion efficiently.

**82. B** — For a zero-order reaction, the half-life is $C_0/(2k) = 10/(2 \times 2.5) = 2$ min. Unlike first order, this half-life depends on the initial concentration.

**83. A** — A larger pre-exponential factor A yields a higher rate constant, since $k = A \cdot \exp(-E_a/RT)$. The factor reflects collision frequency and orientation, independent of the energy barrier.

**84. D** — Lowering the temperature shifts a reversible exothermic reaction toward products, raising the equilibrium conversion. The trade-off is slower kinetics, which a catalyst can offset.

**85. A** — A rate that doubles when concentration doubles indicates first order, since $(2)^1 = 2$. Determining order from concentration–rate data is the standard kinetic method.

**86. C** — A coked catalyst is regenerated by burning off the carbon deposits in a controlled stream of air, restoring the active surface. This regeneration is routine in catalytic cracking and reforming.

**87. D** — Future worth is $P(1 + i)^n = 12{,}000 \times 1.07^5 = 12{,}000 \times 1.4026 = \$16{,}831$. Compounding grows the sum forward at the stated rate.

**88. D** — The six-tenths rule gives $500{,}000 \times (80/20)^{0.6} = 500{,}000 \times 2.297 = \$1{,}149{,}000$. Quadrupling capacity raises cost only about 2.3-fold, reflecting the economy of scale.

**89. C** — Simple payback is capital over annual return, 900,000/300,000 = 3 years. The measure is quick but ignores the time value of money.

**90. A** — Present worth of the annuity is 4000 × 5.3349 = $21,340. The annuity factor sums the discounted value of all eight payments.

**91. C** — The process flow diagram carries the stream table of flows, compositions, and conditions, making it the basis for the material and energy balance. It is more detailed than the block flow diagram but less than the P&ID.

**92. C** — The economic optimum insulation thickness minimises the sum of the insulation cost, which rises with thickness, and the heat-loss cost, which falls with thickness. Balancing these opposing trends gives the best thickness.

**93. B** — Updating with the cost index gives 60,000 × (650/500) = $78,000. The index ratio corrects the historical cost for inflation.

**94. D** — A shell-and-tube exchanger handles large heat duties between clean fluids efficiently and is the standard workhorse for such service. Its robust design accommodates high pressures and large areas.

**95. C** — Geometric similarity requires the larger unit to keep the same shape with all linear dimensions scaled in proportion. Preserving these ratios is the first requirement of reliable scale-up.

**96. A** — Dilute sulphuric acid at moderate temperature is best contained by a corrosion-resistant polymer or rubber lining that resists chemical attack. Carbon steel and aluminium would corrode rapidly in this service.

**97. C** — Critical safety instrumentation is installed with redundant voting arrangements, such as two-out-of-three, so that a single failure does not defeat the protection. Redundancy raises both reliability and safe availability.

**98. D** — A controller combining proportional, integral, and derivative action is a PID controller. It balances fast response, offset elimination, and anticipation of error trends.

**99. C** — A proportional-only controller leaves a steady-state offset because some persistent error is required to generate the corrective output. Adding integral action removes this residual offset.

**100. A** — A Bourdon tube measures pressure by the elastic deflection of a curved tube as internal pressure rises. It is a common mechanical pressure gauge.

**101. D** — A fail-open valve on a cooling-water line moves fully open on loss of signal, ensuring cooling continues, which is the safe state. Selecting the fail position to drive the process to safety is a core design principle.

**102. A** — A vapour–air mixture between its lower and upper flammability limits is ignitable and will burn if a source is present. Keeping streams outside this range is a primary fire-prevention measure.

**103. B** — Removing or reducing the hazard at its source is the most reliable risk reduction, because it eliminates the danger rather than managing it. Lower-tier controls such as PPE depend on correct human use.

**104. D** — The TLV-TWA is the threshold limit value as an eight-hour time-weighted average exposure limit. It defines the safe average concentration for a normal work shift.

**105. C** — A fire involving combustible metals such as magnesium is a Class D fire, requiring a special dry-powder extinguishing agent. Water can react violently with such metals and must be avoided.

**106. D** — The first priority in a major chemical release is to protect people and evacuate as needed, since life safety comes before property or product. Containment and cleanup follow once personnel are safe.

**107. D** — Falsifying test results to meet a deadline is a serious ethics violation, breaching the duties of honesty and public protection. Such conduct can endanger users and carries severe professional consequences.

**108. A** — When pressured to overlook a safety defect, the engineer must uphold public safety and escalate the concern, consistent with the paramount ethical duty. Complying silently would breach that duty.

**109. A** — Life-cycle design accounts for impacts from raw-material extraction through end-of-life disposal, not just one stage. This whole-life view is central to sustainable engineering.

**110. D** — Reproducing a patented process commercially without a licence is patent infringement, since a patent grants the holder exclusive rights for its term. Doing so exposes the infringer to legal liability.