

PRACTICE EXAM 19: FE CHEMICAL SIMULATION (110 QUESTIONS)

Mathematics

1. What is the general solution of the first-order equation $y' - 5y = 0$?

- A. $y = Ce^{(5x)}$
- B. $y = Ce^{(-5x)}$
- C. $y = C \cdot \cos(5x)$
- D. $y = 5x + C$

2. Evaluate the definite integral of the constant 3 from $x = 0$ to $x = 4$.

- A. 3
- B. 4
- C. 7
- D. 12

3. A system of linear equations has a unique solution when its coefficient matrix is:

- A. Non-singular
- B. Singular
- C. The zero matrix
- D. Symmetric

4. What is the derivative of $x^{1/2}$ with respect to x ?

- A. \sqrt{x}
- B. $1/(2\sqrt{x})$
- C. $2\sqrt{x}$
- D. $x^{-1/2}$

5. Evaluate the limit of $\sin(2x)/x$ as x approaches 0.

- A. 0
- B. 1
- C. 0.5
- D. 2

6. What is the unit vector in the direction of $(3, 4)$?

- A. $(0.6, 0.8)$
- B. $(3, 4)$
- C. $(0.3, 0.4)$
- D. $(1, 1)$

Probability and Statistics

7. A single fair die is rolled. What is the probability of obtaining an even number?

- A. 0.33
- B. 0.5
- C. 0.17

D. 0.67

8. What is the arithmetic mean of the data set 2, 4, 6, 8, and 10?

A. 5

B. 4

C. 8

D. 6

9. In how many ways can 3 items be chosen from 8 distinct items, where order does not matter?

A. 24

B. 336

C. 64

D. 56

10. If the probability of event A is 0.35, what is the probability that A does not occur?

A. 0.35

B. 0.65

C. 1.35

D. 0

11. A binomial process has 40 trials with a success probability of 0.25. What is the expected number of successes?

A. 40

B. 10

C. 0.25

D. 7.5

Engineering Sciences

12. A constant 120 N force moves an object 2.5 m in the direction of the force. How much work is done?

A. 300 J

B. 48 J

C. 122.5 J

D. 117.5 J

13. Two $8\ \Omega$ resistors are connected in parallel. What is the equivalent resistance?

A. $4\ \Omega$

B. $16\ \Omega$

C. $8\ \Omega$

D. $0.25\ \Omega$

14. A net force accelerates a 6 kg mass at $3\ \text{m/s}^2$. What is the magnitude of the force?

A. 2 N

B. 18 N

C. 9 N

D. 0.5 N

15. A device draws 3 A at 12 V. What electrical power does it consume?

A. 36 W

- B. 4 W
- C. 15 W
- D. 0.25 W

Materials Science

16. Two bars of identical dimensions but different materials carry the same load. The bar with the higher Young's modulus will:

- A. Deform less
- B. Deform more
- C. Fail first
- D. Corrode faster

17. Fatigue failure typically begins at:

- A. The geometric centre
- B. A region of zero stress
- C. The coolest point
- D. A stress concentration such as a notch or surface flaw

18. Case hardening produces a component with a:

- A. Soft surface and a brittle core
- B. Uniform hardness throughout
- C. Hard surface and a tougher core
- D. Molten outer layer

19. Sacrificial anodes used to protect a steel ship's hull are typically made of:

- A. Zinc or magnesium
- B. Gold or platinum
- C. Copper or brass
- D. Lead or tin

20. Heating a cold-worked metal above its recrystallisation temperature causes:

- A. New strain-free grains to form, softening the metal
- B. The metal to melt completely
- C. Permanent embrittlement
- D. An increase in hardness

Chemistry and Biology

21. An aqueous solution has a hydrogen ion concentration of 1×10^{-8} mol/L. What is its pH?

- A. 6
- B. 1×10^{-8}
- C. 7
- D. 8

22. What is the molar mass of calcium carbonate, CaCO_3 ?

- A. 56 g/mol
- B. 60 g/mol
- C. 84 g/mol
- D. 100 g/mol

23. A fixed quantity of gas occupies 8 L at 1 atm. At constant temperature, what volume does it occupy at 2 atm?

- A. 16 L
- B. 4 L
- C. 8 L
- D. 2 L

24. Adding a catalyst to a reaction already at equilibrium:

- A. Shifts it toward the products
- B. Shifts it toward the reactants
- C. Increases the final yield
- D. Does not change the equilibrium position

25. For $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$ with excess oxygen, how many moles of carbon dioxide form from 5 mol of methane?

- A. 10 mol
- B. 2.5 mol
- C. 5 mol
- D. 1 mol

26. In iron(III) oxide, Fe_2O_3 , the oxidation state of iron is:

- A. +3
- B. +2
- C. -3
- D. 0

27. A weak acid in water:

- A. Fully dissociates
- B. Does not dissolve
- C. Forms a strong base
- D. Only partially dissociates

28. The green pigment in plants that absorbs light for photosynthesis is:

- A. Haemoglobin
- B. Chlorophyll
- C. Melanin
- D. Keratin

Fluid Mechanics

29. A fluid (density 1000 kg/m^3 , viscosity $0.0075 \text{ Pa}\cdot\text{s}$) flows at 0.3 m/s through a 0.1 m pipe. What is the Reynolds number?

- A. 400
- B. 4000
- C. 40000
- D. 800

30. Flow at 3 m/s in a 0.12 m^2 duct enters a 0.04 m^2 section. What is the velocity in the smaller section?

- A. 1 m/s
- B. 3 m/s
- C. 9 m/s

D. 6 m/s

31. In a horizontal pipe, the point of highest velocity corresponds to the point of:

A. Lowest static pressure

B. Highest static pressure

C. Highest elevation

D. Zero flow

32. What is the hydrostatic pressure at a depth of 7 m in water (density 1000 kg/m³)?

A. 7 kPa

B. 68.7 kPa

C. 687 kPa

D. 6.87 kPa

33. For laminar pipe flow at a Reynolds number of 400, what is the Darcy friction factor?

A. 64

B. 4.0

C. 0.016

D. 0.16

34. A pump delivers 0.025 m³/s of water against a head of 16 m. What is the ideal hydraulic power?

A. 0.39 kW

B. 3.92 kW

C. 39.2 kW

D. 392 W

35. A flow of $0.36 \text{ m}^3/\text{s}$ passes through a duct of cross-sectional area 0.06 m^2 . What is the velocity?

A. 0.17 m/s

B. 0.02 m/s

C. 6 m/s

D. 60 m/s

36. Using the Darcy equation with $f = 0.025$, $L = 80 \text{ m}$, $D = 0.1 \text{ m}$, and $v = 2 \text{ m/s}$, what is the head loss?

A. 4.08 m

B. 8.16 m

C. 2.04 m

D. 1.02 m

37. A venturi meter measures flow rate from the:

A. Pressure drop across a converging–diverging section

B. Temperature change of the fluid

C. Colour of the fluid

D. Vibration of the pipe

Thermodynamics

38. A Carnot engine operates between 600 K and 150 K. What is its maximum efficiency?

A. 50%

- B. 75%
- C. 25%
- D. 40%

39. Four moles of an ideal gas ($C_v = 25 \text{ J/mol}\cdot\text{K}$) are heated by 12 K at constant volume. What is the change in internal energy?

- A. 600 J
- B. 1200 J
- C. 2400 J
- D. 300 J

40. A closed system has its internal energy raised by 500 J while doing 400 J of work. How much heat was added?

- A. 100 J
- B. 500 J
- C. 900 J
- D. 400 J

41. Steam enters an adiabatic turbine at 3200 kJ/kg and leaves at 2900 kJ/kg, flowing at 7 kg/s. What is the shaft power?

- A. 300 kW
- B. 1050 kW
- C. 2100 kW
- D. 4200 kW

42. A refrigerator removes 900 W from the cold space while consuming 300 W of work. What is its coefficient of performance?

- A. 4.0
- B. 3.0
- C. 0.33
- D. 2.0

43. An equimolar liquid mixture of A (pure vapour pressure 130 kPa) and B (70 kPa) follows Raoult's law. What is the bubble-point pressure?

- A. 100 kPa
- B. 130 kPa
- C. 70 kPa
- D. 200 kPa

44. Applying the Gibbs phase rule to a pure substance at its triple point gives a number of degrees of freedom of:

- A. 1
- B. 2
- C. 0
- D. 3

45. The entropy of a substance generally increases when it changes from:

- A. Gas to liquid to solid
- B. Liquid to solid
- C. Gas to solid directly
- D. Solid to liquid to gas

46. For a reaction at constant temperature and pressure, spontaneity is determined by the sign of:

- A. ΔG
- B. ΔH alone
- C. ΔS alone
- D. ΔU alone

Material and Energy Balances

47. A 2000 kg/h feed is separated into a 1200 kg/h product and a second product. What is the second product's flow rate?

- A. 800 kg/h
- B. 3200 kg/h
- C. 1200 kg/h
- D. 2000 kg/h

48. An evaporator concentrates 1500 kg/h of a 10% solids feed to a 25% solids product. How much water is evaporated?

- A. 600 kg/h
- B. 150 kg/h
- C. 1350 kg/h
- D. 900 kg/h

49. Complete combustion of carbon follows $C + O_2 \rightarrow CO_2$. How many moles of carbon dioxide form from 5 mol of carbon?

- A. 5 mol
- B. 10 mol
- C. 2.5 mol

D. 1 mol

50. A 100 kg stream of 20% salt is mixed with a 400 kg stream of 45% salt. What is the salt content of the mixture?

A. 20%

B. 40%

C. 45%

D. 32.5%

51. A reactor is fed 600 mol of A, of which 150 mol leaves unreacted. What is the conversion?

A. 25%

B. 100%

C. 75%

D. 150 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

C. 3

D. 1000

53. How much heat is required to raise 12 kg of water by 25 °C, with a specific heat of 4.18 kJ/kg·K?

A. 313 kJ

B. 1254 kJ

C. 627 kJ

D. 2508 kJ

54. A solid has a moisture content of 33.3% on a dry basis. What is the equivalent moisture content on a wet basis?

A. 33.3%

B. 25%

C. 50%

D. 66.7%

55. In the reaction $4A \rightarrow 3B$, 8 mol of A reacts completely. How many moles of B are formed?

A. 6 mol

B. 8 mol

C. 12 mol

D. 4 mol

56. A burner needs 12 mol of oxygen stoichiometrically but is supplied with 15 mol. What is the percentage excess oxygen?

A. 20%

B. 80%

C. 25%

D. 125%

57. Recycling unreacted reactant back to the reactor primarily improves the:

A. Reactor temperature

B. Catalyst lifetime

- C. Overall conversion of feed
- D. Product colour

Heat Transfer

58. A 0.16 m thick wall ($k = 2 \text{ W/m}\cdot\text{K}$, area 3 m^2) has a $40 \text{ }^\circ\text{C}$ temperature difference across it. What is the conductive heat rate?

- A. 750 W
- B. 1500 W
- C. 3000 W
- D. 600 W

59. A 4 m^2 surface transfers 1200 W by convection with a temperature difference of $15 \text{ }^\circ\text{C}$. What is the convective heat-transfer coefficient?

- A. $80 \text{ W/m}^2\cdot\text{K}$
- B. $60 \text{ W/m}^2\cdot\text{K}$
- C. $20 \text{ W/m}^2\cdot\text{K}$
- D. $5 \text{ W/m}^2\cdot\text{K}$

60. The net radiant heat exchange between two surfaces depends on the difference in the:

- A. First powers of their temperatures
- B. Squares of their temperatures
- C. Fourth powers of their absolute temperatures
- D. Cubes of their temperatures

61. In a counter-current exchanger, the hot stream cools from 140 °C to 100 °C while the cold stream warms from 50 °C to 80 °C. What is the log-mean temperature difference?

- A. 55 °C
- B. 54.9 °C
- C. 50 °C
- D. 60 °C

62. Two wall layers have thermal resistances of 0.5 K/W each, in series. What is the total resistance?

- A. 1.0 K/W
- B. 0.25 K/W
- C. 0.5 K/W
- D. 0.1 K/W

63. Two convective films, each 300 W/m²·K, act in series with negligible wall resistance. What is the overall coefficient U?

- A. 600 W/m²·K
- B. 300 W/m²·K
- C. 100 W/m²·K
- D. 150 W/m²·K

64. An exchanger has $U = 400 \text{ W/m}^2 \cdot \text{K}$, area 5 m², 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. A counter-current exchanger is generally preferred over a co-current one because it:

- A. Is always cheaper to build
- B. Needs no pumps
- C. Achieves a larger mean temperature difference and better heat recovery
- D. Eliminates fouling

66. Nucleate boiling is characterised by:

- A. A continuous vapour film over the surface
- B. No bubble formation at all
- C. Vapour bubbles forming at discrete sites on the heated surface
- D. Solidification of the liquid

Mass Transfer and Separation

67. A species diffuses through a 2 mm film with $D = 4 \times 10^{-9} \text{ m}^2/\text{s}$ and a concentration difference of 25 mol/m³. What is the molar flux?

- A. $1 \times 10^{-4} \text{ mol/m}^2 \cdot \text{s}$
- B. $2.5 \times 10^{-5} \text{ mol/m}^2 \cdot \text{s}$
- C. $1 \times 10^{-7} \text{ mol/m}^2 \cdot \text{s}$
- D. $5 \times 10^{-5} \text{ mol/m}^2 \cdot \text{s}$

68. For a relative volatility of 4, what vapour composition is in equilibrium with a liquid of mole fraction 0.25?

- A. 0.25
- B. 0.40
- C. 0.57
- D. 0.80

69. Stripping is favoured when the stripping factor $S = mV/L$ is:

- A. Less than zero
- B. Greater than one
- C. Exactly zero
- D. Negative

70. A solute with a distribution coefficient of 2 is contacted once with an equal volume of solvent. What fraction transfers to the extract?

- A. 0.50
- B. 0.67
- 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. 20
- C. 3.0
- D. 1.0

72. Low temperature and high pressure favour:

- A. Stripping
- B. Distillation alone
- C. Crystallisation
- D. Absorption

73. Molecular diffusion in a gas occurs because of:

- A. The random thermal motion of molecules
- B. An applied electric field
- C. Gravity alone
- D. Magnetic forces

74. The reflux in a distillation column is the portion of the overhead condensate that is:

- A. Drawn off as product
- B. Sent to the reboiler
- C. Returned to the top of the column
- D. Vented to the atmosphere

75. Dialysis separates solutes by:

- A. Applied high pressure alone
- B. An electric field alone
- C. Boiling the mixture
- D. Diffusion across a membrane driven by a concentration difference

Solids Handling

76. A 120 μm particle ($\Delta\rho = 1000 \text{ kg/m}^3$) settles in a fluid of viscosity $1 \times 10^{-3} \text{ Pa}\cdot\text{s}$. What is its Stokes' law terminal velocity?

- A. $1.6 \times 10^{-2} \text{ m/s}$
- B. $3.9 \times 10^{-3} \text{ m/s}$
- C. $1.96 \times 10^{-2} \text{ m/s}$
- D. $7.85 \times 10^{-3} \text{ m/s}$

77. An elutriation classifier separates particles by:

- A. Magnetic attraction
- B. Colour sorting
- C. An upward fluid flow that carries the fine particles away
- D. Heating the mixture

78. As the gas velocity through a packed bed is raised past minimum fluidisation, the bed:

- A. Becomes a rigid solid
- B. Behaves like a boiling liquid
- C. Collapses to zero volume
- D. Stops the gas flow

79. The bulk density of a powder is generally:

- A. Higher than its true particle density
- B. Lower than its true particle density
- C. Equal to its true particle density
- D. Always zero

Chemical Reaction Engineering

80. A first-order reaction ($k = 0.3 \text{ min}^{-1}$) starts at 4 mol/L. What is the concentration after 10 minutes, using $C = C_0 e^{-kt}$ ($e^{-3} = 0.050$)?

- A. 2.0 mol/L
- B. 1.0 mol/L
- C. 0.74 mol/L
- D. 0.20 mol/L

81. A first-order reaction ($k = 0.2 \text{ min}^{-1}$) runs in a PFR with a space time of 5 minutes. What conversion is achieved, using $X = 1 - e^{-k\tau}$?

- A. 0.50
- B. 0.86
- C. 0.63
- D. 0.95

82. A first-order reaction ($k = 0.1 \text{ min}^{-1}$) reaches 50% conversion in a CSTR. What space time is required?

- A. 10 min
- B. 5 min
- C. 2 min
- D. 20 min

83. A first-order reaction has a rate constant of 0.231 min^{-1} . What is its half-life, $t_{1/2} = 0.693/k$?

- A. 30 min
- B. 15 min

C. 6 min

D. 3 min

84. For the reversible reaction $A \rightleftharpoons B$, the forward rate constant is 21 and the reverse is 7. What is the equilibrium constant?

A. 3

B. 14

C. 0.33

D. 28

85. Plotting $\ln k$ against $1/T$ for a reaction gives a straight line whose slope equals:

A. E_a/R

B. E_a

C. $-E_a/R$

D. R/E_a

86. A plug-flow reactor is characterised by:

A. Complete back-mixing

B. No mixing in the direction of flow

C. A single batch charge

D. Zero residence time

Engineering Economics

87. What is the future worth of \$25,000 invested for 5 years at 4% interest ($1.04^5 = 1.2167$)?

- A. \$26,000
- B. \$28,000
- C. \$29,500
- D. \$30,417

88. What is the present worth of \$45,000 to be received in 4 years at 6% interest ($1.06^4 = 1.2625$)?

- A. \$40,000
- B. \$35,644
- C. \$45,000
- D. \$56,813

89. A \$120,000 asset with a \$12,000 salvage value is depreciated straight-line over 9 years. What is the annual depreciation?

- A. \$13,333
- B. \$12,000
- C. \$14,000
- D. \$108,000

90. A \$250,000 investment yields an annual profit of \$50,000. What is the simple return on investment?

- A. 20%
- B. 5%
- C. 50%
- D. 2%

Process Design

91. A study (factored) capital cost estimate is typically based on:
- A. Detailed vendor quotes for every item
 - B. The final as-built cost
 - C. Labour hours alone
 - D. The cost of major equipment scaled by Lang factors
92. A common strategy to reduce the energy use of a distillation column is:
- A. Raising the reflux ratio to infinity
 - B. Removing the reboiler
 - C. Adding more inert gas
 - D. Heat integration or feed preheating
93. Equipment that cost \$300,000 at a cost index of 750 is re-estimated at a current index of 1000. What is the updated cost?
- A. \$225,000
 - B. \$300,000
 - C. \$400,000
 - D. \$500,000
94. For continuously separating two immiscible liquids of different density, a suitable unit is:
- A. A decanter (gravity settler)
 - B. A packed distillation column
 - C. A fired heater

D. A cyclone for gases

95. To move a viscous liquid at a steady, controlled rate, a suitable choice is:

A. A positive-displacement pump

B. A centrifugal fan

C. An ejector alone

D. A gravity siphon

96. A vent stack disperses released gases by:

A. Condensing them to a liquid

B. Storing them under pressure

C. Discharging them at height to aid dilution

D. Cooling the reactor

97. For a vessel operating at very high temperature in an oxidising atmosphere, a suitable material is:

A. A heat-resistant stainless or nickel alloy

B. Ordinary PVC

C. Uncoated mild steel

D. Plain aluminium

Process Control

98. Adding integral action to a proportional controller primarily:

A. Speeds the initial response alone

- B. Amplifies measurement noise
- C. Adds dead time
- D. Eliminates the steady-state offset

99. An orifice-plate flow meter infers the flow rate from the:

- A. Temperature rise
- B. Pressure drop it creates
- C. Colour of the fluid
- D. Fluid conductivity

100. A control valve specified as "fail-closed" will, on loss of its actuating signal:

- A. Stay where it is
- B. Open fully
- C. Modulate to half open
- D. Move to the fully closed position

101. Excessive derivative action in a controller tends to:

- A. Remove the steady-state offset
- B. Slow the response alone
- C. Add integral windup
- D. Amplify measurement noise

Safety, Health, and Environment

102. The lower explosive limit of a gas is the:

- A. Maximum concentration that will burn
- B. Boiling point of the gas
- C. Minimum concentration in air that will support combustion
- D. Flash point temperature

103. The preferred first step in managing a process hazard is to:

- A. Issue more personal protective equipment
- B. Add warning labels
- C. Write an operating procedure
- D. Eliminate or substitute the hazard at its source

104. Before entering a confined space, the most critical check is the:

- A. Atmosphere for oxygen and toxic or flammable gases
- B. Paint colour of the walls
- C. Outside weather
- D. The worker's lunch break time

105. The discharge from a relief valve handling a toxic gas should be routed to a:

- A. Nearby open drain
- B. The operator's control room
- C. Flare or scrubber, not the open air
- D. The cooling tower

106. The principal cause of stratospheric ozone depletion was the release of:

- A. Carbon dioxide
- B. Methane
- C. Chlorofluorocarbons (CFCs)
- D. Nitrogen

Ethics and Professional Practice

107. The first canon of most engineering codes of ethics is to hold paramount the:

- A. Interests of the employer
- B. Speed of project delivery
- C. Engineer's own reputation
- D. Safety, health, and welfare of the public

108. An engineer must issue public statements only in a manner that is:

- A. Persuasive and one-sided
- B. Objective and truthful
- C. Favourable to the client
- D. Simplified and exaggerated

109. An engineer serving as an impartial arbiter must:

- A. Accept the highest bidder's view
- B. Remain silent about any interest
- C. Disclose any interest that could affect their judgement
- D. Favour the larger company

110. Incorporating waste minimisation and energy efficiency into a design reflects an engineer's commitment to:

- A. Maximising short-term profit
- B. Sustainable development
- C. Minimising documentation
- D. Avoiding all regulation

Practice Exam 19 – Answer Key and Explanations

1. **A** — Separating $dy/dx = 5y$ gives $y = Ce^{(5x)}$, exponential growth proportional to the current value. The positive exponent reflects a quantity rising at a rate set by the constant 5.
2. **D** — The integral of a constant is the constant times the interval, $3 \times (4 - 0) = 12$. Integrating a constant gives the area of a rectangle.
3. **A** — A linear system has a unique solution when its coefficient matrix is non-singular, with a nonzero determinant. A singular matrix gives either no solution or infinitely many.
4. **B** — By the power rule, the derivative of $x^{(1/2)}$ is $\frac{1}{2}x^{(-1/2)}$, which equals $1/(2\sqrt{x})$. The exponent of one-half produces the factor of one-half.
5. **D** — Using $\sin(2x) \approx 2x$ for small x , the limit of $\sin(2x)/x$ is 2. The argument's coefficient carries through to the limit.
6. **A** — Dividing $(3, 4)$ by its magnitude of 5 gives the unit vector $(0.6, 0.8)$. Normalising preserves direction while setting the length to one.
7. **B** — Three of the six equally likely faces are even, so the probability is $3/6 = 0.5$. Half the outcomes satisfy the condition.
8. **D** — The mean is the sum over the count, $(2 + 4 + 6 + 8 + 10)/5 = 30/5 = 6$. For evenly spaced data the mean equals the central value.
9. **D** — The number of combinations is $C(8,3) = 8!/(3!5!) = 56$. Combinations count unordered selections.
10. **B** — The complement rule gives $P(\text{not } A) = 1 - P(A) = 1 - 0.35 = 0.65$. An event and its complement always sum to one.

- 11. B** — The mean of a binomial distribution is $np = 40 \times 0.25 = 10$. This gives the expected number of successes.
- 12. A** — Work is force times distance, $120 \times 2.5 = 300$ J. The force acts along the direction of motion, so all of it does work.
- 13. A** — Two equal resistors in parallel give half the value, $8/2 = 4 \Omega$. The parallel result is always less than either individual resistor.
- 14. B** — Newton's second law gives $F = ma = 6 \times 3 = 18$ N. Force is the product of mass and acceleration.
- 15. A** — Electrical power is current times voltage, $P = IV = 3 \times 12 = 36$ W. This relation governs the power drawn by a device.
- 16. A** — The bar with the higher Young's modulus is stiffer, so under the same load it deforms less. Stiffness measures resistance to elastic deformation.
- 17. D** — Fatigue cracks typically initiate at stress concentrations such as notches, holes, or surface flaws, where local stress is amplified. Eliminating sharp features greatly extends fatigue life.
- 18. C** — Case hardening hardens only the surface layer of a component while leaving a tougher, more ductile core beneath. This combination resists surface wear yet withstands impact without shattering.
- 19. A** — Sacrificial anodes are made of more active metals such as zinc or magnesium, which corrode in place of the protected steel. Their lower electrode potential makes them the preferential anode.
- 20. A** — Above the recrystallisation temperature, a cold-worked metal forms new strain-free grains, relieving the work hardening and softening the metal. This restores ductility for further forming.
- 21. D** — With $[H^+] = 10^{-8}$, the pH is $-\log(10^{-8}) = 8$. This value is slightly basic, just above neutral.
- 22. D** — Summing atomic masses, $Ca (40) + C (12) + 3O (48) = 100$ g/mol. Molar mass converts between mass and moles in stoichiometry.
- 23. B** — By Boyle's law at constant temperature, doubling the pressure halves the volume, so 8 L becomes 4 L. Pressure and volume vary inversely.
- 24. D** — A catalyst speeds the forward and reverse reactions equally, so it does not change the equilibrium position, only the time to reach it. The final yield is set by thermodynamics, not by the catalyst.
- 25. C** — The one-to-one carbon stoichiometry gives one mole of carbon dioxide per mole of methane, so 5 mol of methane yields 5 mol. Methane is the limiting reactant with oxygen in excess.
- 26. A** — With three oxygens at -2 giving -6 , the two irons must total $+6$, so each iron is $+3$. This is iron's higher common oxidation state.

- 27. D** — A weak acid only partially dissociates in water, establishing an equilibrium between the undissociated acid and its ions. This incomplete ionisation distinguishes it from a strong acid.
- 28. B** — Chlorophyll is the green pigment that absorbs light energy to drive photosynthesis. Its absorption of red and blue light, reflecting green, gives plants their colour.
- 29. B** — Reynolds number is $\rho v D / \mu = (1000 \times 0.3 \times 0.1) / 0.0075 = 4000$. This value lies just into the turbulent regime.
- 30. C** — Continuity gives $v_2 = v_1 A_1 / A_2 = 3 \times (0.12 / 0.04) = 9$ m/s. The threefold area reduction triples the velocity.
- 31. A** — By Bernoulli's principle in a horizontal pipe, the point of highest velocity has the lowest static pressure, conserving total head. This inverse relationship underlies venturi and orifice metering.
- 32. B** — Hydrostatic pressure is $\rho g h = 1000 \times 9.81 \times 7 = 68,670$ Pa ≈ 68.7 kPa. Pressure rises linearly with depth.
- 33. D** — For laminar flow, the friction factor is $64 / \text{Re} = 64 / 400 = 0.16$. The inverse dependence on Reynolds number gives higher friction at lower flow.
- 34. B** — Ideal hydraulic power is $\rho g Q H = 1000 \times 9.81 \times 0.025 \times 16 = 3924$ W ≈ 3.92 kW. Dividing by efficiency would give the shaft power.
- 35. C** — Velocity is flow over area, $0.36 / 0.06 = 6$ m/s. This follows directly from the continuity equation.
- 36. A** — The Darcy equation gives $h_f = f(L/D)(v^2/2g) = 0.025 \times (80/0.1) \times (4/19.62) = 4.08$ m. Friction head loss scales with the square of velocity.
- 37. A** — A venturi meter measures flow from the pressure drop developed across its converging–diverging throat, by Bernoulli's equation. The recovered diverging section keeps the permanent pressure loss low.
- 38. B** — Carnot efficiency is $1 - T_c / T_h = 1 - 150 / 600 = 0.75$, or 75%. The large temperature ratio raises the theoretical ceiling.
- 39. B** — Internal energy change at constant volume is $n C_v \Delta T = 4 \times 25 \times 12 = 1200$ J. The constant-volume heat capacity applies because no work is done.
- 40. C** — The first law gives $Q = \Delta U + W = 500 + 400 = 900$ J. Heat supplied both raises internal energy and does work.
- 41. C** — Adiabatic turbine power is $\dot{m}(h_1 - h_2) = 7 \times (3200 - 2900) = 2100$ kW. The enthalpy drop converts directly into shaft work.
- 42. B** — Refrigerator COP is $Q_c / W = 900 / 300 = 3.0$. The device moves more heat than the work it consumes, the basis of efficient cooling.

- 43. A** — Raoult's law gives the bubble pressure as $0.5 \times 130 + 0.5 \times 70 = 100$ kPa. The total pressure is the mole-fraction-weighted sum of the pure vapour pressures.
- 44. C** — At the triple point of a pure substance, three phases coexist, so the Gibbs phase rule $F = C - P + 2 = 1 - 3 + 2 = 0$ gives zero degrees of freedom. The triple point is therefore a fixed, unique state.
- 45. D** — Entropy increases through the sequence solid \rightarrow liquid \rightarrow gas, as the molecular disorder and number of accessible arrangements rise. The gas state has by far the greatest entropy.
- 46. A** — At constant temperature and pressure, the sign of the Gibbs free energy change ΔG determines spontaneity, being negative for a spontaneous reaction. It combines the enthalpy and entropy contributions.
- 47. A** — A steady-state mass balance gives the second product as $2000 - 1200 = 800$ kg/h. Conservation of mass closes the separation.
- 48. D** — A solids balance gives $0.10 \times 1500 = 0.25 \times L$, so the product is $L = 600$ kg/h, and water evaporated = $1500 - 600 = 900$ kg/h. The non-volatile solids fix the product rate.
- 49. A** — At one mole of carbon dioxide per mole of carbon, 5 mol of carbon yields 5 mol of CO_2 . The combustion conserves the carbon atoms.
- 50. B** — The combined salt is $0.20 \times 100 + 0.45 \times 400 = 20 + 180 = 200$ kg in 500 kg, giving 40%. A component balance yields the blended composition.
- 51. C** — Conversion is $(600 - 150)/600 = 75\%$. This fraction measures how completely the feed is consumed.
- 52. C** — The recycle ratio is recycle over fresh feed, $750/250 = 3$. It characterises the process's reliance on recycling.
- 53. B** — Sensible heat is $mC_p\Delta T = 12 \times 4.18 \times 25 = 1254$ kJ. This relation sizes the heating duty for a temperature change.
- 54. B** — Converting 33.3% dry basis gives wet basis = $33.3/(100 + 33.3) = 25\%$. The wet basis is the smaller figure because its denominator includes the water.
- 55. A** — The stoichiometry produces three moles of B per four of A, so 8 mol of A yields 6 mol of B. Reaction stoichiometry converts reactant consumed into product formed.
- 56. C** — Percentage excess is $(15 - 12)/12 = 25\%$. The surplus oxygen ensures complete combustion.
- 57. C** — Recycling unreacted reactant returns it to the reactor, raising the overall conversion of the fresh feed even when the per-pass conversion is modest. This makes efficient use of valuable reactants.

- 58. B** — Fourier's law gives $Q = kA\Delta T/L = (2 \times 3 \times 40)/0.16 = 1500 \text{ W}$. Conductive heat rate scales with conductivity, area, and driving temperature.
- 59. C** — Rearranging $Q = hA\Delta T$ gives $h = 1200/(4 \times 15) = 20 \text{ W/m}^2\cdot\text{K}$. The coefficient measures how effectively the fluid removes heat.
- 60. C** — Net radiant exchange between two surfaces depends on the difference in the fourth powers of their absolute temperatures, from the Stefan–Boltzmann law. This makes radiation strongly favour the hotter surface.
- 61. B** — With $\Delta T_1 = 140 - 80 = 60 \text{ }^\circ\text{C}$ and $\Delta T_2 = 100 - 50 = 50 \text{ }^\circ\text{C}$, the log-mean is $(60 - 50)/\ln(60/50) = 54.9 \text{ }^\circ\text{C}$. The LMTD is the correct mean driving force, just below the arithmetic mean of $55 \text{ }^\circ\text{C}$.
- 62. A** — Series thermal resistances add directly, $0.5 + 0.5 = 1.0 \text{ K/W}$. The thermal-circuit analogy makes composite-wall analysis straightforward.
- 63. D** — With negligible wall resistance, $1/U = 1/300 + 1/300 = 0.00667$, so $U = 150 \text{ W/m}^2\cdot\text{K}$. Two equal series films halve the overall coefficient.
- 64. D** — Exchanger duty is $UA\Delta T = 400 \times 5 \times 30 = 60,000 \text{ W} = 60 \text{ kW}$. This product of coefficient, area, and driving force sizes the exchanger.
- 65. C** — A counter-current exchanger maintains a larger and more uniform mean temperature difference than a co-current one, giving better heat recovery and allowing the cold stream to exceed the hot outlet. This efficiency is why counter-current is the usual choice.
- 66. C** — Nucleate boiling is marked by vapour bubbles forming at discrete nucleation sites on the heated surface, giving very high heat-transfer rates. It is the desired, efficient regime before the critical heat flux is reached.
- 67. D** — Fick's law gives flux $= D \cdot \Delta C / \delta = (4 \times 10^{-9} \times 25) / (2 \times 10^{-3}) = 5 \times 10^{-5} \text{ mol/m}^2\cdot\text{s}$. Flux rises with diffusivity and concentration difference and falls with film thickness.
- 68. C** — Using $y = \alpha x / [1 + (\alpha - 1)x] = (4 \times 0.25) / (1 + 3 \times 0.25) = 1.0 / 1.75 = 0.57$. The vapour is enriched in the volatile component relative to the liquid.
- 69. B** — Stripping is favoured when the stripping factor $S = mV/L$ exceeds one, meaning the gas capacity outstrips the liquid's hold on the solute. A value below one instead favours absorption.
- 70. B** — For equal volumes with $K = 2$, the fraction extracted is $K/(K + 1) = 2/3 = 0.67$. A higher distribution coefficient sends more solute to the extract.
- 71. C** — The number of transfer units is $\ln(C_{\text{in}}/C_{\text{out}}) = \ln(20) \approx 3.0$. NTU rises with the fractional removal demanded.

72. D — Low temperature and high pressure both increase gas solubility, favouring absorption of a gas into a liquid. The reverse conditions favour stripping the gas back out.

73. A — Molecular diffusion in a gas arises from the random thermal motion of its molecules, which net-transport species down a concentration gradient. No external force is needed for this spontaneous mixing.

74. C — The reflux is the part of the condensed overhead that is returned to the top of the column, rather than withdrawn as product. It provides the descending liquid needed for the counter-current contacting.

75. D — Dialysis separates solutes by their diffusion across a semipermeable membrane, driven by the concentration difference between the two sides. Small solutes pass while larger species are retained.

76. D — Stokes' law gives $v = gd^2\Delta\rho/(18\mu) = (9.81 \times (1.2 \times 10^{-4})^2 \times 1000)/(18 \times 10^{-3}) = 7.85 \times 10^{-3}$ m/s. The square dependence on diameter makes settling highly size-sensitive.

77. C — An elutriation classifier uses an upward fluid stream to carry away the fine particles while the coarse ones settle against it. The cut size is set by matching the fluid velocity to the particles' terminal velocity.

78. B — Past minimum fluidisation, the suspended bed takes on liquid-like behaviour, bubbling and flowing as gas passes through. This fluid-like state gives excellent mixing and heat transfer.

79. B — The bulk density of a powder is lower than its true particle density because it includes the void space between particles. This is why a given mass of powder occupies more volume than the solid alone.

80. D — First-order decay gives $C = C_0e^{-kt} = 4 \times e^{-(0.3 \times 10)} = 4 \times e^{-3} = 4 \times 0.050 = 0.20$ mol/L. The concentration falls exponentially at a rate fixed by k .

81. C — For a first-order PFR, conversion is $X = 1 - e^{-k\tau} = 1 - e^{-(0.2 \times 5)} = 1 - e^{-1} = 0.63$. This conversion is reached at a space time of one time constant.

82. A — For a first-order CSTR, $\tau = X/[k(1 - X)] = 0.5/(0.1 \times 0.5) = 10$ min. The space time links reactor size to the conversion achieved.

83. D — The first-order half-life is $0.693/k = 0.693/0.231 = 3$ min. This half-life is independent of concentration, the signature of first-order kinetics.

84. A — At equilibrium the forward and reverse rates balance, so $K = k_{\text{forward}}/k_{\text{reverse}} = 21/7 = 3$. This links the kinetic constants to the equilibrium position.

85. C — Plotting $\ln k$ against $1/T$ linearises the Arrhenius equation, giving a straight line of slope $-E_a/R$. The slope thus yields the activation energy.

86. B — A plug-flow reactor has no mixing in the direction of flow, so each fluid element moves through as a discrete plug with its own residence time. This gives the highest conversion per unit volume for positive-order kinetics.

- 87. D** — Future worth is $P(1 + i)^n = 25,000 \times 1.04^5 = 25,000 \times 1.2167 = \$30,417$. Compounding grows the sum forward at the stated rate.
- 88. B** — Present worth is $F/(1 + i)^n = 45,000/1.06^4 = 45,000/1.2625 = \$35,644$. Discounting reflects that a future sum is worth less today.
- 89. B** — Straight-line depreciation is $(120,000 - 12,000)/9 = \$12,000$ per year. This even allocation spreads the depreciable basis across the service life.
- 90. A** — Return on investment is annual profit over investment, $50,000/250,000 = 20\%$. It expresses the yearly earnings as a fraction of the capital committed.
- 91. D** — A study, or factored, estimate is built from the cost of the major equipment scaled up by Lang factors to account for installation, piping, and other costs. This gives a quick estimate before detailed design.
- 92. D** — Distillation energy use is commonly cut through heat integration or feed preheating, which recover and reuse heat within the process. These measures reduce the external reboiler and condenser duties.
- 93. C** — Updating with the cost index gives $300,000 \times (1000/750) = \$400,000$. The index ratio corrects the historical cost for inflation.
- 94. A** — A decanter, or gravity settler, continuously separates two immiscible liquids by allowing the denser phase to settle and be drawn off below the lighter one. The density difference drives the separation.
- 95. A** — A positive-displacement pump moves a viscous liquid at a steady, controlled rate, since each cycle delivers a fixed volume regardless of viscosity. Centrifugal pumps lose performance with viscous fluids.
- 96. C** — A vent stack discharges released gases at height so that wind and atmospheric turbulence dilute them before they reach ground level. The elevation improves dispersion and reduces ground-level concentrations.
- 97. A** — A vessel at very high temperature in an oxidising atmosphere requires a heat-resistant stainless or nickel alloy that resists scaling and retains strength. Ordinary metals and plastics would oxidise or soften.
- 98. D** — Integral action accumulates the error over time and adjusts the output until the error reaches zero, eliminating the steady-state offset left by proportional action alone. This drives the variable exactly to set point.
- 99. B** — An orifice-plate meter infers flow rate from the pressure drop it creates as the fluid accelerates through the restriction, by Bernoulli's equation. The square root of the pressure drop is proportional to the flow.

100. D — A fail-closed valve moves to the fully closed position when its actuating signal is lost, the safe state for many services. The fail position is chosen so a failure leaves the process safe.

101. D — Derivative action responds to the rate of change of the error and so amplifies any high-frequency measurement noise. Excessive derivative gain therefore makes the loop jittery and is often filtered.

102. C — The lower explosive limit is the minimum vapour-in-air concentration that will support combustion; below it the mixture is too lean to ignite. It bounds the lower edge of the flammable range.

103. D — The preferred first step in hazard management is to eliminate or substitute the hazard at its source, since this removes the risk rather than merely guarding against it. Lower-tier controls only reduce exposure to a hazard that remains.

104. A — Before confined-space entry, the most critical check is testing the atmosphere for adequate oxygen and the absence of toxic or flammable gases. An unrecognised hazardous atmosphere is the leading cause of confined-space fatalities.

105. C — The discharge from a relief valve handling toxic gas must be routed to a flare or scrubber that destroys or captures it, never released to the open air. This protects workers and the surrounding area from the toxic release.

106. C — Chlorofluorocarbons were the principal cause of stratospheric ozone depletion, releasing chlorine that catalytically destroys ozone. Their phase-out under the Montreal Protocol addressed this damage.

107. D — The first canon of most engineering codes of ethics is to hold paramount the safety, health, and welfare of the public. This duty takes precedence over obligations to employer or client.

108. B — Engineers must make public statements only in an objective and truthful manner, founded on the facts. Misleading or biased public communication undermines trust and can endanger the public.

109. C — An engineer acting as an impartial arbiter must disclose any interest that could affect their judgement, preserving the integrity of the role. Hidden interests would compromise the fairness expected of an arbiter.

110. B — Designing for waste minimisation and energy efficiency reflects a commitment to sustainable development, balancing present needs against future resource and environmental stewardship. This is a core obligation of modern engineering practice.

ERROR REPORT: None.

That completes the answer key, explanations, and error report for **Practice Exam 19** — and with it, **all 19 simulation exams of Part Two are now fully finished** (questions, locked keys, explanations, and clean error reports throughout).

What remains to finish the title is the back matter (Appendix A acronym list, Appendix B glossary, the companion-website/QR bridging section, and the full front matter — copyright page, trademark disclaimer, exam-affiliation disclaimer, and disclaimer of guarantee) and the KDP marketing package (Amazon description in the Alex Hormozi style, primary and backup category recommendations, USP power phrases of four words or fewer, and the title-case confirmation). Tell me which you'd like to tackle next.