

PRACTICE EXAM 18: FE CHEMICAL SIMULATION (110 QUESTIONS)

Mathematics

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

- A. $y = C_1e^x + C_2e^{-x}$
- B. $y = C_1\cos(x) + C_2\sin(x)$
- C. $y = (C_1 + C_2x)e^x$
- D. $y = C_1e^x$

2. Evaluate the definite integral of x from $x = 1$ to $x = 3$.

- A. 4
- B. 8
- C. 2
- D. 9

3. The rank of a matrix equals the number of:

- A. Linearly independent rows or columns
- B. Total entries
- C. Zero rows
- D. Diagonal elements

4. What is the derivative of $e^{(3x)}$ with respect to x ?

- A. $e^{(3x)}$
- B. $3x \cdot e^{(3x)}$
- C. $3e^{(3x)}$
- D. $e^{(3x)}/3$

5. Evaluate the limit of $(x^2 - 9)/(x - 3)$ as x approaches 3.

- A. 0
- B. 9
- C. 3
- D. 6

6. A 50 N force acts at 30° to the horizontal. What is its horizontal component ($\cos 30^\circ = 0.866$)?

- A. 25 N
- B. 50 N
- C. 58 N
- D. 43.3 N

Probability and Statistics

7. A bag holds 3 red and 7 blue balls. What is the probability of drawing a red ball?

- A. 0.70
- B. 0.30
- C. 0.43
- D. 0.10

8. What is the mode of the data set 8, 8, 8, 12, and 15?

- A. 8
- B. 12
- C. 10.2
- D. 15

9. In how many ordered ways can 2 items be selected from 5 distinct items?

- A. 10
- B. 25
- C. 120
- D. 20

10. A distribution with a long tail extending to the right is described as:

- A. Symmetric
- B. Negatively skewed
- C. Uniform
- D. Positively skewed

11. A bet pays +\$20 with probability 0.25 and loses \$4 with probability 0.75. What is the expected value?

- A. \$2
- B. \$16
- C. -\$4
- D. \$20

Engineering Sciences

12. An 80 N force moves an object 5 m at 60° to the displacement. How much work is done ($\cos 60^\circ = 0.5$)?

- A. 400 J
- B. 200 J
- C. 80 J
- D. 346 J

13. Three resistors of $3\ \Omega$, $6\ \Omega$, and $11\ \Omega$ are connected in series. What is the total resistance?

- A. $20\ \Omega$
- B. $1.7\ \Omega$
- C. $198\ \Omega$
- D. $10\ \Omega$

14. An object accelerates uniformly from 10 m/s to 30 m/s in 4 seconds. What is its acceleration?

- A. $5\ \text{m/s}^2$
- B. $0.2\ \text{m/s}^2$
- C. $7.5\ \text{m/s}^2$
- D. $2.5\ \text{m/s}^2$

15. A current of 3 A flows through a $7\ \Omega$ resistor. What is the voltage across it?

- A. 0.43 V
- B. 2.33 V
- C. 10 V

D. 21 V

Materials Science

16. The slope of the linear elastic region of a stress–strain curve is the:

- A. Young's modulus
- B. Yield strength
- C. Ultimate strength
- D. Fracture strain

17. Poisson's ratio relates the lateral strain to the:

- A. Axial strain
- B. Applied stress
- C. Shear modulus
- D. Temperature

18. At the eutectic point of a binary phase diagram, a liquid transforms directly into:

- A. A single pure solid
- B. Two solid phases simultaneously
- C. A gas
- D. A supercooled liquid alone

19. The corrosion rate of a metal generally increases with:

- A. Lower temperature alone

- B. Complete dryness
- C. Higher purity alone
- D. Rising temperature and oxygen availability

20. In a fibre-reinforced composite, the fibres primarily provide:

- A. Strength and stiffness along their length
- B. Electrical insulation alone
- C. Thermal mass
- D. Corrosion of the matrix

Chemistry and Biology

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

- A. 5
- B. 9
- C. 7
- D. 1×10^{-5}

22. What is the molar mass of sulphur dioxide, SO₂?

- A. 32 g/mol
- B. 48 g/mol
- C. 80 g/mol
- D. 64 g/mol

23. A fixed quantity of gas occupies 4 L at 200 K. At constant pressure, what volume does it occupy at 500 K?

- A. 1.6 L
- B. 4 L
- C. 10 L
- D. 6 L

24. Doubling the concentration of a reactant in a first-order reaction:

- A. Quadruples the rate
- B. Halves the rate
- C. Has no effect
- D. Doubles the rate

25. The decomposition $2\text{KClO}_3 \rightarrow 2\text{KCl} + 3\text{O}_2$ goes to completion. How many moles of oxygen form from 4 mol of potassium chlorate?

- A. 6 mol
- B. 4 mol
- C. 2 mol
- D. 12 mol

26. What is the molarity of a solution containing 0.25 mol of solute in 500 mL of solution?

- A. 0.125 M
- B. 2 M
- C. 0.5 M
- D. 1.25 M

27. A heterogeneous catalyst accelerates a reaction by:

- A. Adsorbing reactants onto its surface
- B. Dissolving fully in the reactants
- C. Raising the temperature
- D. Adding extra reactant

28. The basic structural and functional unit of all living organisms is the:

- A. Atom
- B. Cell
- C. Molecule
- D. Organ

Fluid Mechanics

29. A fluid (density 1000 kg/m^3 , viscosity $0.001 \text{ Pa}\cdot\text{s}$) flows at 2 m/s through a 0.1 m pipe. What is the Reynolds number?

- A. 2000
- B. 20000
- C. 200000
- D. 400

30. Flow at 4 m/s in a 0.1 m^2 duct enters a 0.02 m^2 section. What is the velocity in the smaller section?

- A. 0.8 m/s
- B. 4 m/s
- C. 8 m/s
- D. 20 m/s

31. As water flows up a narrowing pipe that also rises, the total head remains:
- A. Always increasing
 - B. Constant in the absence of friction
 - C. Always decreasing
 - D. Zero
32. What is the hydrostatic pressure at a depth of 3 m in water (density 1000 kg/m³)?
- A. 3 kPa
 - B. 29.4 kPa
 - C. 294 kPa
 - D. 2.94 kPa
33. For laminar pipe flow at a Reynolds number of 256, what is the Darcy friction factor?
- A. 64
 - B. 2.56
 - C. 0.25
 - D. 0.025
34. A pump delivers 0.05 m³/s of water against a head of 12 m. What is the ideal hydraulic power?
- A. 0.59 kW
 - B. 5.89 kW
 - C. 58.9 kW
 - D. 589 W

35. A flow of $0.4 \text{ m}^3/\text{s}$ passes through a duct of cross-sectional area 0.08 m^2 . What is the velocity?

- A. 0.2 m/s
- B. 5 m/s
- C. 0.032 m/s
- D. 50 m/s

36. Using the Darcy equation with $f = 0.02$, $L = 100 \text{ m}$, $D = 0.1 \text{ m}$, and $v = 2 \text{ m/s}$, what is the head loss?

- A. 2.04 m
- B. 8.16 m
- C. 4.08 m
- D. 1.02 m

37. A gas flow is generally treated as incompressible when its Mach number is:

- A. Above 1
- B. Exactly 1
- C. Below about 0.3
- D. Above 5

Thermodynamics

38. A Carnot engine operates between 400 K and 300 K . What is its maximum efficiency?

- A. 75%
- B. 50%
- C. 40%

D. 25%

39. Two moles of an ideal gas ($C_p = 35 \text{ J/mol}\cdot\text{K}$) are heated by 20 K at constant pressure. What is the enthalpy change?

A. 700 J

B. 350 J

C. 1400 J

D. 2800 J

40. A closed system has its internal energy raised by 200 J while doing 300 J of work. How much heat was added?

A. -100 J

B. 200 J

C. 500 J

D. 100 J

41. Steam enters an adiabatic turbine at 3300 kJ/kg and leaves at 2900 kJ/kg, flowing at 5 kg/s. What is the shaft power?

A. 400 kW

B. 2000 kW

C. 4000 kW

D. 1000 kW

42. A heat pump delivers 900 W of heat while consuming 300 W of work. What is its heating coefficient of performance?

A. 4

- B. 5
- C. 0.33
- D. 3

43. An equimolar liquid mixture of A (pure vapour pressure 150 kPa) and B (90 kPa) follows Raoult's law. What is the bubble-point pressure?

- A. 120 kPa
- B. 90 kPa
- C. 150 kPa
- D. 240 kPa

44. At equilibrium, the Gibbs free energy change of a reaction is:

- A. Positive
- B. Negative
- C. Zero
- D. At its maximum

45. A reversible adiabatic process is also:

- A. Isentropic
- B. Isothermal
- C. Isobaric
- D. Isochoric

46. Superheated steam is steam that is:

- A. At its boiling point exactly

- B. A mixture of liquid and vapour
- C. Below the saturation temperature
- D. Heated above its saturation temperature at a given pressure

Material and Energy Balances

47. Two feed streams of 600 kg/h and 400 kg/h are combined in a mixer. What is the product flow rate at steady state?

- A. 1000 kg/h
- B. 200 kg/h
- C. 600 kg/h
- D. 400 kg/h

48. An evaporator concentrates 1000 kg/h of a 6% solids feed to a 30% solids product. What is the product flow rate?

- A. 200 kg/h
- B. 60 kg/h
- C. 800 kg/h
- D. 240 kg/h

49. Combustion follows $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$. How many moles of oxygen are needed for 6 mol of hydrogen?

- A. 6 mol
- B. 3 mol
- C. 12 mol
- D. 1.5 mol

50. A 300 kg stream of 10% salt is mixed with a 200 kg stream of 35% salt. What is the salt content of the mixture?

- A. 10%
- B. 20%
- C. 35%
- D. 22.5%

51. A reactor is fed 1200 mol of A, of which 300 mol leaves unreacted. What is the conversion?

- A. 25%
- B. 100%
- C. 75%
- D. 300 mol

52. A process recycles 800 mol/h and receives a fresh feed of 200 mol/h. What is the recycle ratio?

- A. 0.25
- B. 1
- C. 4
- D. 1000

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

- A. 522 kJ
- B. 1045 kJ
- C. 4180 kJ
- D. 2090 kJ

54. A solid has a moisture content of 50% on a dry basis. What is the equivalent moisture content on a wet basis?

- A. 50%
- B. 33.3%
- C. 66.7%
- D. 25%

55. In the reaction $2A \rightarrow 5B$, 4 mol of A reacts completely. How many moles of B are formed?

- A. 4 mol
- B. 5 mol
- C. 8 mol
- D. 10 mol

56. A burner needs 40 mol of oxygen stoichiometrically but is supplied with 50 mol. What is the percentage excess oxygen?

- A. 25%
- B. 20%
- C. 80%
- D. 125%

57. The theoretical (stoichiometric) air for combustion is the:

- A. Twice the actual amount supplied
- B. Always 20% above the actual amount
- C. Air remaining after combustion
- D. Exact amount needed for complete combustion

Heat Transfer

58. A 0.04 m thick wall ($k = 1.2 \text{ W/m}\cdot\text{K}$, area 2 m^2) has a $50 \text{ }^\circ\text{C}$ temperature difference across it. What is the conductive heat rate?

- A. 600 W
- B. 1500 W
- C. 3000 W
- D. 6000 W

59. A 4 m^2 surface transfers heat by convection with $h = 25 \text{ W/m}^2\cdot\text{K}$ and a temperature difference of $40 \text{ }^\circ\text{C}$. What is the heat rate?

- A. 4000 W
- B. 2000 W
- C. 1000 W
- D. 8000 W

60. If the absolute temperature of a radiating surface is doubled, by what factor does its radiative heat loss increase?

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

61. In a counter-current exchanger, the hot stream cools from $150 \text{ }^\circ\text{C}$ to $90 \text{ }^\circ\text{C}$ while the cold stream warms from $40 \text{ }^\circ\text{C}$ to $70 \text{ }^\circ\text{C}$. What is the log-mean temperature difference?

- A. $65 \text{ }^\circ\text{C}$

- B. 55 °C
- C. 70 °C
- D. 63.8 °C

62. Two wall layers have thermal resistances of 0.8 K/W and 0.7 K/W in series. What is the total resistance?

- A. 0.56 K/W
- B. 0.75 K/W
- C. 1.5 K/W
- D. 0.1 K/W

63. Two convective films, each 400 W/m²·K, act in series with negligible wall resistance. What is the overall coefficient U?

- A. 800 W/m²·K
- B. 200 W/m²·K
- C. 400 W/m²·K
- D. 100 W/m²·K

64. An exchanger has $U = 500 \text{ W/m}^2 \cdot \text{K}$, area 4 m², and a log-mean temperature difference of 15 °C. What is the heat duty?

- A. 6 kW
- B. 15 kW
- C. 30 kW
- D. 60 kW

65. A heat exchanger in which both fluids flow in the same direction is a:

- A. Counter-current exchanger
- B. Cross-flow exchanger
- C. Regenerator
- D. Parallel-flow (co-current) exchanger

66. Gases generally have:

- A. Higher thermal conductivity than metals
- B. Much lower thermal conductivity than metals
- C. Zero thermal conductivity
- D. Infinite thermal conductivity

Mass Transfer and Separation

67. A species diffuses through a 1 mm film with $D = 2 \times 10^{-9} \text{ m}^2/\text{s}$ and a concentration difference of 20 mol/m^3 . What is the molar flux?

- A. $2 \times 10^{-5} \text{ mol/m}^2 \cdot \text{s}$
- B. $4 \times 10^{-5} \text{ mol/m}^2 \cdot \text{s}$
- C. $8 \times 10^{-5} \text{ mol/m}^2 \cdot \text{s}$
- D. $4 \times 10^{-8} \text{ mol/m}^2 \cdot \text{s}$

68. For a relative volatility of 6, what vapour composition is in equilibrium with a liquid of mole fraction 0.1?

- A. 0.40
- B. 0.10
- C. 0.60
- D. 0.80

69. Distillation separates components on the basis of differences in their:

- A. Volatility (boiling points)
- B. Colour
- C. Density alone
- D. Molar mass alone

70. A solute with a distribution coefficient of 1 is contacted once with an equal volume of solvent. What fraction transfers to the extract?

- A. 0.75
- B. 0.25
- C. 0.50
- D. 0.33

71. A dilute absorber removes 96% of a solute, so $C_{in}/C_{out} = 25$. What is the number of transfer units, $NTU = \ln(C_{in}/C_{out})$?

- A. 0.96
- B. 25
- C. 2.0
- D. 3.2

72. In a packed absorption column, the packing serves to:

- A. Heat the gas
- B. Increase the gas–liquid contact area
- C. Filter out solids
- D. Reduce the liquid flow

73. Crystallisation separates a solute from solution by:

- A. Boiling off the solute
- B. Magnetic separation
- C. Cooling or evaporating until the solute exceeds its solubility
- D. Dissolving more solvent

74. The overall column efficiency relates the number of:

- A. Trays to downcomers
- B. Pumps to columns
- C. Ideal stages to actual stages
- D. Inlets to outlets

75. The driving force in pervaporation is the:

- A. Temperature gradient alone
- B. Applied electric field
- C. Gravitational force
- D. Difference in component partial pressure across the membrane

Solids Handling

76. An 80 μm particle ($\Delta\rho = 2500 \text{ kg/m}^3$) settles in a fluid of viscosity $1 \times 10^{-3} \text{ Pa}\cdot\text{s}$. What is its Stokes' law terminal velocity?

- A. $8.72 \times 10^{-3} \text{ m/s}$
- B. $1.7 \times 10^{-2} \text{ m/s}$
- C. $4.4 \times 10^{-3} \text{ m/s}$

D. 2.5×10^{-2} m/s

77. A filter aid such as diatomaceous earth is used to:

- A. Dissolve the suspended solids
- B. Heat the slurry
- C. Improve the permeability of the filter cake
- D. Colour the filtrate

78. The power required by an agitator in a stirred tank depends strongly on the:

- A. Tank colour
- B. Liquid colour
- C. Ambient lighting
- D. Impeller speed and diameter

79. A mass-flow hopper is designed so that:

- A. Only the central core flows
- B. All the material moves whenever any is withdrawn
- C. The powder never flows out
- D. Material flows only when vibrated

Chemical Reaction Engineering

80. A first-order reaction ($k = 0.05 \text{ min}^{-1}$) starts at 8 mol/L. What is the concentration after 20 minutes, using $C = C_0 e^{-kt}$?

- A. 2.94 mol/L
- B. 4.0 mol/L

- C. 0.37 mol/L
- D. 1.0 mol/L

81. A first-order reaction ($k = 0.4 \text{ min}^{-1}$) runs in a PFR with a space time of 5 minutes. What conversion is achieved, using $X = 1 - e^{(-k\tau)}$?

- A. 0.63
- B. 0.86
- C. 0.78
- D. 0.95

82. A first-order reaction ($k = 0.4 \text{ min}^{-1}$) reaches 80% conversion in a CSTR. What space time is required?

- A. 2 min
- B. 4 min
- C. 20 min
- D. 10 min

83. A zero-order reaction has $k = 3 \text{ mol/L}\cdot\text{min}$ and an initial concentration of 12 mol/L. What is its half-life, $t_{1/2} = C_0/(2k)$?

- A. 2 min
- B. 4 min
- C. 6 min
- D. 1 min

84. For the reversible reaction $A \rightleftharpoons B$, the forward rate constant is 16 and the reverse is 4. What is the equilibrium constant?

- A. 4
- B. 20
- C. 0.25
- D. 12

85. A reversible exothermic reaction operated at higher temperature shows:

- A. A lower rate and a higher conversion
- B. No change in either
- C. A higher rate but a lower equilibrium conversion
- D. Complete conversion at all temperatures

86. An autocatalytic reaction is one in which:

- A. The catalyst is consumed
- B. A product also acts as a catalyst
- C. No catalyst exists
- D. The rate is always constant

Engineering Economics

87. What is the future worth of \$20,000 invested for 6 years at 5% interest ($1.05^6 = 1.3401$)?

- A. \$23,000
- B. \$24,500
- C. \$25,200
- D. \$26,802

88. What is the present worth of \$60,000 to be received in 4 years at 8% interest ($1.08^4 = 1.3605$)?

- A. \$50,000
- B. \$48,000
- C. \$44,102
- D. \$60,000

89. A \$200,000 asset with a \$40,000 salvage value is depreciated straight-line over 8 years. What is the annual depreciation?

- A. \$25,000
- B. \$20,000
- C. \$22,500
- D. \$160,000

90. What is the capitalised cost of a perpetual annual expense of \$15,000 at an interest rate of 5%, using $P = A/i$?

- A. \$75,000
- B. \$750
- C. \$15,750
- D. \$300,000

Process Design

91. A flow sheet showing the mass and energy balances for each stream is part of the:

- A. Plot plan
- B. Process flow diagram

- C. Wiring diagram
- D. Organisation chart

92. Most of the energy cost in a distillation column is associated with the:

- A. Reflux pump
- B. Feed valve
- C. Reboiler heat duty
- D. Instrumentation

93. Equipment that cost \$250,000 at a cost index of 500 is re-estimated at a current index of 600. What is the updated cost?

- A. \$208,333
- B. \$300,000
- C. \$250,000
- D. \$350,000

94. For a highly exothermic gas-phase reaction needing tight temperature control, a suitable design is:

- A. A multitubular fixed-bed reactor with cooling
- B. An open stirred pond
- C. A simple adiabatic batch flask
- D. A gravity settling tank

95. For piping that carries seawater, a corrosion-resistant material choice is:

- A. Plain carbon steel
- B. Ordinary cast iron

- C. Untreated mild steel
- D. A cupronickel or other suitable alloy

96. The available net positive suction head must exceed the required value to prevent:

- A. Motor overheating
- B. Pipe corrosion
- C. Cavitation in the pump
- D. Valve sticking

97. A pinch analysis sets targets for the minimum:

- A. Number of pumps
- B. Hot and cold utility requirements
- C. Pipe diameters
- D. Number of control valves

Process Control

98. A controller output that swings fully between two extreme positions is characteristic of:

- A. Proportional control
- B. On–off control
- C. Derivative control
- D. Cascade control

99. A Bourdon tube is a mechanical device used to measure:

- A. Temperature
- B. Flow
- C. Pressure
- D. Level

100. In a feedback control loop, the element that compares the measurement with the set point is the:

- A. Comparator (error detector)
- B. Final control element
- C. Process
- D. Transmitter

101. A first-order process responds to a step input with an output that approaches its final value:

- A. Instantly
- B. Linearly
- C. With overshoot in all cases
- D. Exponentially

Safety, Health, and Environment

102. The three elements of the fire triangle are fuel, an ignition source, and:

- A. Water
- B. Pressure
- C. Nitrogen
- D. Oxygen

103. A safety data sheet provides information on a chemical's:

- A. Market price alone
- B. Hazards, handling, and emergency measures
- C. Supplier's address alone
- D. Packaging colour

104. The most effective measure in the hierarchy of controls is to:

- A. Provide personal protective equipment
- B. Post warning signs
- C. Eliminate the hazard
- D. Add an alarm

105. A hot-work permit is required before performing:

- A. Routine office tasks
- B. Ordinary cleaning
- C. Welding or other spark-producing work in a hazardous area
- D. Reading a gauge

106. The primary greenhouse gas released by the anaerobic digestion of organic waste is:

- A. Carbon dioxide
- B. Methane
- C. Oxygen
- D. Nitrogen

Ethics and Professional Practice

107. When professional duty conflicts with an employer's instruction to cut a safety corner, the engineer should:

- A. Uphold the duty to public safety
- B. Follow the instruction without question
- C. Resign immediately and say nothing
- D. Delegate the decision to others

108. An engineer should perform services only in areas of their:

- A. Highest pay
- B. Personal interest
- C. Competence
- D. Employer's choosing

109. Confidential client information learned during a project:

- A. May be shared freely
- B. Can be sold to competitors
- C. Must not be disclosed or used for personal gain
- D. Belongs to the engineer

110. Engineers issuing public technical statements should ensure they are:

- A. Favourable to their employer
- B. As brief as possible
- C. Persuasive above all

D. Objective and founded on adequate knowledge

Practice Exam 18 – Answer Key and Explanations

- 1. B** — The characteristic equation $r^2 + 1 = 0$ gives imaginary roots $r = \pm i$, producing the oscillatory solution $C_1\cos(x) + C_2\sin(x)$. Imaginary roots always yield sine–cosine solutions, the form of simple harmonic motion.
- 2. A** — The antiderivative of x is $x^2/2$, evaluated from 1 to 3 as $(9 - 1)/2 = 4$. Definite integration accumulates the area under the line.
- 3. A** — The rank of a matrix is the number of linearly independent rows, which equals the number of linearly independent columns. It measures the dimension of the space the matrix spans.
- 4. C** — By the chain rule, the derivative of $e^{(3x)}$ is $3e^{(3x)}$. The factor of 3 comes from differentiating the exponent.
- 5. D** — Factoring gives $(x^2 - 9)/(x - 3) = (x + 3)$, so the limit as $x \rightarrow 3$ is 6. Cancelling the common factor removes the removable discontinuity.
- 6. D** — The horizontal component is $F \cdot \cos \theta = 50 \times \cos 30^\circ = 50 \times 0.866 = 43.3$ N. Resolving a force uses the cosine of the angle to the direction of interest.
- 7. B** — The probability of drawing a red ball is $3/(3 + 7) = 3/10 = 0.30$. Each ball is equally likely to be selected.
- 8. A** — The mode is the most frequently occurring value, which is 8 (appearing three times). The mode identifies the data's most common observation.
- 9. D** — The ordered selection count is $P(5,2) = 5 \times 4 = 20$. Permutations count arrangements where order matters.
- 10. D** — A distribution with a long right-hand tail is positively (right) skewed, with its mean pulled above its median. The direction of the tail names the skew.
- 11. A** — The expected value is $0.25 \times 20 - 0.75 \times 4 = 5 - 3 = \2 . It is the probability-weighted average of the outcomes.
- 12. B** — Work is $Fd \cdot \cos \theta = 80 \times 5 \times \cos 60^\circ = 80 \times 5 \times 0.5 = 200$ J. Only the component of force along the displacement does work.
- 13. A** — Series resistances add directly, $3 + 6 + 11 = 20 \Omega$. The series total always exceeds any single resistor.

- 14. A** — Acceleration is the change in velocity over time, $(30 - 10)/4 = 5 \text{ m/s}^2$. Uniform acceleration relates velocity change to elapsed time linearly.
- 15. D** — Ohm's law gives $V = IR = 3 \times 7 = 21 \text{ V}$. Voltage is proportional to both current and resistance.
- 16. A** — The slope of the linear elastic region of a stress–strain curve is Young's modulus, the measure of stiffness. It relates stress to strain while the material deforms elastically.
- 17. A** — Poisson's ratio is the ratio of lateral (transverse) strain to axial (longitudinal) strain under load. It describes how a material thins as it is stretched.
- 18. B** — At the eutectic point, a liquid of fixed composition transforms on cooling directly into two solid phases at once. This invariant reaction occurs at a single temperature.
- 19. D** — Corrosion generally accelerates with rising temperature, which speeds the reactions, and with greater oxygen availability, which feeds the cathodic process. Both factors increase the rate of metal loss.
- 20. A** — In a fibre-reinforced composite, the high-strength fibres carry most of the load and provide stiffness along their length. The matrix binds them and transfers load between them.
- 21. A** — With $[H^+] = 10^{-5}$, the pH is $-\log(10^{-5}) = 5$. This value is mildly acidic, below neutral.
- 22. D** — Summing atomic masses, $S (32) + 2O (32) = 64 \text{ g/mol}$. Molar mass converts between mass and moles in stoichiometry.
- 23. C** — By Charles's law at constant pressure, volume is proportional to absolute temperature, so $V_2 = 4 \times (500/200) = 10 \text{ L}$. Heating the gas expands it in proportion to its absolute temperature.
- 24. D** — For a first-order reaction, the rate is directly proportional to concentration, so doubling the concentration doubles the rate. The first-power dependence defines first-order kinetics.
- 25. A** — The two-to-three stoichiometry gives 1.5 moles of oxygen per mole of potassium chlorate, so 4 mol yields 6 mol of O_2 . The decomposition conserves the oxygen atoms.
- 26. C** — Molarity is moles over litres, $0.25/0.500 = 0.5 \text{ M}$. Concentration relates the amount of solute to the solution volume.
- 27. A** — A heterogeneous catalyst works by adsorbing the reactants onto its solid surface, where they react more readily before desorbing. The surface provides the active sites for the lower-energy pathway.
- 28. B** — The cell is the basic structural and functional unit of all living organisms. All life is composed of one or more cells.
- 29. C** — Reynolds number is $\rho vD/\mu = (1000 \times 2 \times 0.1)/0.001 = 200,000$. This strongly turbulent value sets the appropriate friction correlation.

- 30. D** — Continuity gives $v_2 = v_1 A_1 / A_2 = 4 \times (0.1 / 0.02) = 20$ m/s. The fivefold area reduction raises the velocity fivefold.
- 31. B** — In the absence of friction, Bernoulli's equation makes the total head constant along a streamline, with pressure, velocity, and elevation heads trading off. Energy is conserved as the flow rises and narrows.
- 32. B** — Hydrostatic pressure is $\rho gh = 1000 \times 9.81 \times 3 = 29,430$ Pa ≈ 29.4 kPa. Pressure rises linearly with depth.
- 33. C** — For laminar flow, the friction factor is $64 / \text{Re} = 64 / 256 = 0.25$. The inverse dependence on Reynolds number gives higher friction at lower flow.
- 34. B** — Ideal hydraulic power is $\rho gQH = 1000 \times 9.81 \times 0.05 \times 12 = 5886$ W ≈ 5.89 kW. Dividing by efficiency would give the shaft power.
- 35. B** — Velocity is flow over area, $0.4 / 0.08 = 5$ m/s. This follows directly from the continuity equation.
- 36. C** — The Darcy equation gives $h_f = f(L/D)(v^2/2g) = 0.02 \times (100/0.1) \times (4/19.62) = 4.08$ m. Friction head loss scales with the square of velocity.
- 37. C** — A gas flow can be treated as incompressible when its Mach number is below about 0.3, where density changes are negligible. Above this, compressibility effects must be accounted for.
- 38. D** — Carnot efficiency is $1 - T_c / T_h = 1 - 300 / 400 = 0.25$, or 25%. The small temperature ratio limits the theoretical ceiling.
- 39. C** — Enthalpy change at constant pressure is $nC_p \Delta T = 2 \times 35 \times 20 = 1400$ J. The constant-pressure heat capacity accounts for the expansion work.
- 40. C** — The first law gives $Q = \Delta U + W = 200 + 300 = 500$ J. Heat supplied both raises internal energy and does work.
- 41. B** — Adiabatic turbine power is $\dot{m}(h_1 - h_2) = 5 \times (3300 - 2900) = 2000$ kW. The enthalpy drop converts directly into shaft work.
- 42. D** — The heating coefficient of performance is $Q_h / W = 900 / 300 = 3$. The heat pump delivers more heat than the work it consumes.
- 43. A** — Raoult's law gives the bubble pressure as $0.5 \times 150 + 0.5 \times 90 = 120$ kPa. The total pressure is the mole-fraction-weighted sum of the pure vapour pressures.
- 44. C** — At equilibrium, the Gibbs free energy change of a reaction is zero, with no further net drive in either direction. Away from equilibrium, ΔG is negative for the spontaneous direction.
- 45. A** — A reversible adiabatic process is isentropic, since no heat is exchanged and the process is reversible, leaving entropy unchanged. It is the ideal benchmark for compressors and turbines.

- 46. D** — Superheated steam is steam heated above the saturation temperature corresponding to its pressure, containing no liquid. The extra energy raises it beyond the boiling point.
- 47. A** — A steady-state mass balance sums the inlet streams, $600 + 400 = 1000$ kg/h, which must equal the product. Conservation of mass requires output to match input.
- 48. A** — A solids balance gives $0.06 \times 1000 = 0.30 \times L$, so the product is $L = 200$ kg/h. The non-volatile solids fix the product rate.
- 49. B** — At one mole of oxygen per two of hydrogen, 6 mol of hydrogen needs 3 mol. Combustion stoichiometry sets the oxygen demand.
- 50. B** — The combined salt is $0.10 \times 300 + 0.35 \times 200 = 30 + 70 = 100$ kg in 500 kg, giving 20%. A component balance yields the blended composition.
- 51. C** — Conversion is $(1200 - 300)/1200 = 75\%$. This fraction measures how completely the feed is consumed.
- 52. C** — The recycle ratio is recycle over fresh feed, $800/200 = 4$. It characterises the process's reliance on recycling.
- 53. D** — Sensible heat is $mC_p\Delta T = 10 \times 4.18 \times 50 = 2090$ kJ. This relation sizes the heating duty for a temperature change.
- 54. B** — Converting 50% dry basis gives wet basis = $50/(100 + 50) = 33.3\%$. The wet basis is the smaller figure because its denominator includes the water.
- 55. D** — The stoichiometry produces five moles of B per two of A, so 4 mol of A yields 10 mol of B. Reaction stoichiometry converts reactant consumed into product formed.
- 56. A** — Percentage excess is $(50 - 40)/40 = 25\%$. The surplus oxygen ensures complete combustion.
- 57. D** — The theoretical, or stoichiometric, air is the exact amount needed for complete combustion of the fuel. Actual combustion typically uses excess air beyond this amount.
- 58. C** — Fourier's law gives $Q = kA\Delta T/L = (1.2 \times 2 \times 50)/0.04 = 3000$ W. Conductive heat rate scales with conductivity, area, and driving temperature.
- 59. A** — Convective heat rate is $hA\Delta T = 25 \times 4 \times 40 = 4000$ W. The coefficient h reflects how effectively the fluid removes heat.
- 60. A** — Radiative emission scales with the fourth power of absolute temperature, so doubling T raises it by $2^4 = 16$ times. This steep dependence makes radiation dominant at high temperatures.
- 61. D** — With $\Delta T_1 = 150 - 70 = 80$ °C and $\Delta T_2 = 90 - 40 = 50$ °C, the log-mean is $(80 - 50)/\ln(80/50) = 63.8$ °C. The LMTD is the correct mean driving force, below the arithmetic mean of 65 °C.

- 62. C** — Series thermal resistances add directly, $0.8 + 0.7 = 1.5$ K/W. The thermal-circuit analogy makes composite-wall analysis straightforward.
- 63. B** — With negligible wall resistance, $1/U = 1/400 + 1/400 = 0.005$, so $U = 200$ W/m²·K. Two equal series films halve the overall coefficient.
- 64. C** — Exchanger duty is $UA\Delta T = 500 \times 4 \times 15 = 30,000$ W = 30 kW. This product of coefficient, area, and driving force sizes the exchanger.
- 65. D** — When both fluids flow in the same direction, the unit is a parallel-flow or co-current exchanger. Its temperature difference is largest at the inlet and shrinks along the length.
- 66. B** — Gases have much lower thermal conductivity than metals, because their widely spaced molecules transfer energy far less readily. This is why trapped gas, as in foams, makes good insulation.
- 67. B** — Fick's law gives flux = $D \cdot \Delta C / \delta = (2 \times 10^{-9} \times 20) / (1 \times 10^{-3}) = 4 \times 10^{-5}$ mol/m²·s. Flux rises with diffusivity and concentration difference and falls with film thickness.
- 68. A** — Using $y = \alpha x / [1 + (\alpha - 1)x] = (6 \times 0.1) / (1 + 5 \times 0.1) = 0.6 / 1.5 = 0.40$. The vapour is enriched in the volatile component relative to the liquid.
- 69. A** — Distillation separates components according to differences in their volatility, or boiling points, exploiting the more volatile species' tendency to vaporise. This volatility difference drives the separation.
- 70. C** — For equal volumes with $K = 1$, the fraction extracted is $K / (K + 1) = 1/2 = 0.50$. Equal partitioning sends half the solute to the extract in one stage.
- 71. D** — The number of transfer units is $\ln(C_{in}/C_{out}) = \ln(25) \approx 3.2$. NTU rises with the fractional removal demanded.
- 72. B** — The packing in an absorption column increases the gas–liquid contact area, promoting mass transfer between the phases. A larger interfacial area speeds the absorption.
- 73. C** — Crystallisation separates a solute by cooling or evaporating the solution until the solute exceeds its solubility and crystallises out. The supersaturation drives the formation of solid crystals.
- 74. C** — The overall column efficiency is the ratio of the number of ideal (theoretical) stages to the number of actual stages required. It accounts for the non-ideal performance of real trays.
- 75. D** — The driving force in pervaporation is the difference in component partial pressure across the membrane, maintained by applying a vacuum or sweep on the permeate side. This gradient pulls the permeating species through.
- 76. A** — Stokes' law gives $v = gd^2\Delta\rho / (18\mu) = (9.81 \times (8 \times 10^{-5})^2 \times 2500) / (18 \times 10^{-3}) = 8.72 \times 10^{-3}$ m/s. The square dependence on diameter makes settling highly size-sensitive.

- 77. C** — A filter aid such as diatomaceous earth improves the permeability of the filter cake, keeping it open and porous so the filtrate flows freely. It prevents fine particles from blinding the medium.
- 78. D** — The agitator power in a stirred tank depends strongly on the impeller speed and diameter, rising sharply with both. The power number correlation captures this dependence.
- 79. B** — A mass-flow hopper is designed so that all the material is in motion whenever any is withdrawn, with no stagnant zones. This first-in, first-out flow avoids the segregation and caking of funnel flow.
- 80. A** — First-order decay gives $C = C_0 e^{-kt} = 8 \times e^{-(0.05 \times 20)} = 8 \times e^{-1} = 8 \times 0.368 = 2.94$ mol/L. The concentration falls exponentially at a rate fixed by k .
- 81. B** — For a first-order PFR, conversion is $X = 1 - e^{-k\tau} = 1 - e^{-(0.4 \times 5)} = 1 - e^{-2} = 0.86$. The plug-flow reactor reaches high conversion efficiently.
- 82. D** — For a first-order CSTR, $\tau = X/[k(1 - X)] = 0.8/(0.4 \times 0.2) = 10$ min. High conversion in a CSTR demands a long residence time because it operates at the low exit concentration.
- 83. A** — The zero-order half-life is $C_0/(2k) = 12/(2 \times 3) = 2$ min. Unlike first-order, the zero-order half-life depends on the starting concentration.
- 84. A** — At equilibrium the forward and reverse rates balance, so $K = k_{\text{forward}}/k_{\text{reverse}} = 16/4 = 4$. This links the kinetic constants to the equilibrium position.
- 85. C** — For a reversible exothermic reaction, higher temperature speeds the kinetics but lowers the equilibrium conversion, since heat is treated as a product. This trade-off gives an optimal operating temperature.
- 86. B** — An autocatalytic reaction is one in which a product also acts as a catalyst, so the rate accelerates as product accumulates. This self-acceleration gives a characteristic S-shaped conversion curve.
- 87. D** — Future worth is $P(1 + i)^n = 20,000 \times 1.05^6 = 20,000 \times 1.3401 = \$26,802$. Compounding grows the sum forward at the stated rate.
- 88. C** — Present worth is $F/(1 + i)^n = 60,000/1.08^4 = 60,000/1.3605 = \$44,102$. Discounting reflects that a future sum is worth less today.
- 89. B** — Straight-line depreciation is $(200,000 - 40,000)/8 = \$20,000$ per year. This even allocation spreads the depreciable basis across the service life.
- 90. D** — Capitalised cost of a perpetual annual amount is $A/i = 15,000/0.05 = \$300,000$. This perpetuity formula values an endless stream of equal payments as a single sum.
- 91. B** — A flow sheet presenting the mass and energy balances for each stream is part of the process flow diagram. The PFD documents the stream conditions and quantities throughout the process.

- 92. C** — Most of a distillation column's energy cost lies in the reboiler heat duty, which supplies the latent heat to generate vapour. Reducing this duty, through heat integration, is the main route to energy savings.
- 93. B** — Updating with the cost index gives $250,000 \times (600/500) = \$300,000$. The index ratio corrects the historical cost for inflation.
- 94. A** — A highly exothermic gas-phase reaction needing tight temperature control suits a multitubular fixed-bed reactor, where catalyst-filled tubes are surrounded by coolant. The many small tubes give the large surface area needed to remove heat.
- 95. D** — Seawater piping calls for a corrosion-resistant alloy such as cupronickel, which resists the chloride attack that rapidly corrodes carbon steel and iron. Correct material choice prevents premature failure.
- 96. C** — The available net positive suction head must exceed the required value to keep the suction pressure above the liquid's vapour pressure, preventing cavitation. Cavitation forms damaging vapour bubbles in the pump.
- 97. B** — A pinch analysis sets the targets for the minimum hot and cold utility requirements achievable through heat integration. The pinch point limits how much heat can be recovered internally.
- 98. B** — A controller whose output swings fully between two extreme positions is performing on-off control. This simplest control mode cycles the actuator fully open or fully closed around the set point.
- 99. C** — A Bourdon tube is a curved metal tube that straightens under internal pressure, making it a mechanical pressure gauge. The motion of its tip drives the indicating pointer.
- 100. A** — The comparator, or error detector, compares the measured variable with the set point and outputs their difference. This error signal drives the controller's corrective action.
- 101. D** — A first-order process responds to a step input by approaching its final value exponentially, governed by a single time constant. It reaches about 63% of the change in one time constant.
- 102. D** — The fire triangle consists of fuel, an ignition source (heat), and oxygen; removing any one prevents or extinguishes a fire. Oxygen is the oxidiser that sustains combustion.
- 103. B** — A safety data sheet provides information on a chemical's hazards, safe handling, storage, and emergency measures. It is the key reference for working safely with a substance.
- 104. C** — Eliminating the hazard is the most effective control in the hierarchy, since it removes the risk entirely at the source. Lower tiers like PPE only reduce exposure to a hazard that still exists.
- 105. C** — A hot-work permit is required before welding, cutting, or other spark-producing work in a hazardous area, to control ignition risk. The permit ensures the area is checked and made safe first.

106. B — Anaerobic digestion of organic waste releases methane as its primary greenhouse gas, a far more potent warming agent than carbon dioxide. Capturing this methane allows it to be used as a fuel.

107. A — When an employer's instruction would cut a safety corner, the engineer must uphold the paramount duty to public safety over that instruction. This obligation takes precedence over loyalty to the employer.

108. C — An engineer should perform services only in areas of their competence, where they have the necessary training and experience. Working beyond one's competence endangers the public.

109. C — Confidential client information must not be disclosed or used for the engineer's personal gain, even after the project ends. Protecting it preserves the trust essential to the professional relationship.

110. D — Public technical statements by engineers should be objective and founded on adequate knowledge of the facts. This honesty prevents the public from being misled by unsupported or biased claims.