

PRACTICE EXAM 17: FE CHEMICAL SIMULATION (110 QUESTIONS)

Mathematics

1. Solve $dy/dx = 3y$ subject to $y(0) = 2$. Which function results?

A. $y = 2e^{(-3x)}$

B. $y = 2e^{(3x)}$

C. $y = 3e^{(2x)}$

D. $y = 2 + 3x$

2. Evaluate the definite integral of $e^{(2x)}$ from $x = 0$ to $x = 1$ ($e^2 = 7.39$).

A. 7.39

B. 6.39

C. 3.19

D. 1.0

3. The product of a matrix and its inverse is:

A. The identity matrix

B. The zero matrix

C. The transpose

D. A scalar

4. What is the derivative of $\cos(x)$ with respect to x ?

- A. $\sin(x)$
- B. $-\sin(x)$
- C. $-\cos(x)$
- D. $\sec(x)$

5. Evaluate the limit of $(1 - \cos x)/x^2$ as x approaches 0.

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

6. What is the magnitude of the vector $(6, 8)$?

- A. 14
- B. 48
- C. 7
- D. 10

Probability and Statistics

7. Two fair dice are rolled. What is the probability that the sum equals 2?

- A. 0.167
- B. 0.083
- C. 0.50
- D. 0.028

8. What is the arithmetic mean of the data set 10, 20, 30, and 40?

- A. 30
- B. 20
- C. 25
- D. 100

9. In how many ways can 2 items be chosen from 7 distinct items, where order does not matter?

- A. 42
- B. 14
- C. 49
- D. 21

10. For two mutually exclusive events, the probability of A or B equals:

- A. $P(A) \times P(B)$
- B. $P(A) + P(B)$
- C. $P(A) - P(B)$
- D. 1

11. A binomial process has 100 trials with success probability 0.5. What is its variance, $np(1 - p)$?

- A. 50
- B. 100
- C. 5
- D. 25

Engineering Sciences

12. A machine does 600 J of work in 4 seconds. What power does it deliver?

- A. 2400 W
- B. 0.0067 W
- C. 150 W
- D. 604 W

13. Two $10\ \Omega$ resistors are connected in parallel. What is the equivalent resistance?

- A. $20\ \Omega$
- B. $10\ \Omega$
- C. $5\ \Omega$
- D. $0.2\ \Omega$

14. What is the momentum of a 12 kg mass moving at 5 m/s?

- A. $2.4\ \text{kg}\cdot\text{m/s}$
- B. $17\ \text{kg}\cdot\text{m/s}$
- C. $7\ \text{kg}\cdot\text{m/s}$
- D. $60\ \text{kg}\cdot\text{m/s}$

15. What power is dissipated in an $8\ \Omega$ resistor carrying 2 A, using $P = I^2R$?

- A. 16 W
- B. 32 W
- C. 4 W

D. 64 W

Materials Science

16. The capacity of a material to absorb energy elastically and release it on unloading is its:

- A. Toughness
- B. Hardness
- C. Resilience
- D. Creep

17. Engineering stress is defined as the:

- A. Force multiplied by the length
- B. Strain divided by the modulus
- C. Energy per unit area
- D. Applied force divided by the original cross-sectional area

18. Normalising steel involves heating it and then:

- A. Quenching in oil immediately
- B. Air cooling to refine the grain structure
- C. Holding at temperature indefinitely
- D. Cooling in liquid nitrogen

19. Galvanising protects steel by coating it with:

- A. Zinc, which corrodes sacrificially

- B. Gold, which is inert
- C. A thin oxide of iron
- D. A layer of carbon

20. Increasing the degree of cross-linking in a polymer generally:

- A. Makes it more fluid
- B. Lowers only its melting point
- C. Increases its rigidity and reduces its flexibility
- D. Has no measurable effect

Chemistry and Biology

21. An aqueous solution has a hydrogen ion concentration of 1×10^{-3} mol/L. What is its pH?

- A. 3
- B. 11
- C. 7
- D. 1×10^{-3}

22. What is the molar mass of nitrogen dioxide, NO_2 ?

- A. 30 g/mol
- B. 46 g/mol
- C. 44 g/mol
- D. 14 g/mol

23. A fixed quantity of gas occupies 9 L at 1 atm. At constant temperature, what volume does it occupy at 3 atm?

- A. 27 L
- B. 9 L
- C. 1 L
- D. 3 L

24. For an exothermic reaction, lowering the temperature shifts the equilibrium toward:

- A. The products
- B. The reactants
- C. No net change
- D. Stopping the reaction

25. For $\text{N}_2 + \text{O}_2 \rightarrow 2\text{NO}$ with excess oxygen, how many moles of NO form from 3 mol of nitrogen?

- A. 3 mol
- B. 6 mol
- C. 1.5 mol
- D. 9 mol

26. In sodium chloride, the oxidation state of sodium is:

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

27. A buffer solution resists changes in pH when:

- A. Small amounts of acid or base are added
- B. It is heated strongly
- C. It is diluted to infinity
- D. It is frozen

28. The process by which plants release water vapour through their leaves is:

- A. Respiration
- B. Transpiration
- C. Photosynthesis
- D. Digestion

Fluid Mechanics

29. A fluid (density 900 kg/m^3 , viscosity $0.009 \text{ Pa}\cdot\text{s}$) flows at 1 m/s through a 0.04 m pipe. What is the Reynolds number?

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

30. Flow at 8 m/s in a 0.02 m^2 duct enters a 0.08 m^2 section. What is the velocity in the larger section?

- A. 2 m/s
- B. 8 m/s
- C. 32 m/s

D. 16 m/s

31. A pitot tube measures fluid velocity by sensing the:

A. Temperature rise

B. Difference between stagnation and static pressure

C. Density change

D. Viscosity directly

32. What is the hydrostatic pressure at a depth of 5 m in water (density 1000 kg/m³)?

A. 5 kPa

B. 490 kPa

C. 4.91 kPa

D. 49.1 kPa

33. For laminar pipe flow at a Reynolds number of 80, what is the Darcy friction factor?

A. 64

B. 8.0

C. 0.08

D. 0.8

34. A pump delivers 0.03 m³/s of water against a head of 20 m. What is the ideal hydraulic power?

A. 5.89 kW

B. 0.59 kW

C. 58.9 kW

D. 589 W

35. A flow of $0.6 \text{ m}^3/\text{s}$ passes through a duct of cross-sectional area 0.15 m^2 . What is the velocity?

A. 0.25 m/s

B. 4 m/s

C. 0.09 m/s

D. 40 m/s

36. Using the Darcy equation with $f = 0.03$, $L = 50 \text{ m}$, $D = 0.1 \text{ m}$, and $v = 3 \text{ m/s}$, what is the head loss?

A. 3.44 m

B. 13.8 m

C. 6.88 m

D. 1.72 m

37. A Newtonian fluid is one whose:

A. Viscosity depends on the shear rate

B. Shear stress is proportional to the shear rate

C. Density varies with pressure

D. Flow is always turbulent

Thermodynamics

38. A Carnot engine operates between 750 K and 375 K . What is its maximum efficiency?

A. 50%

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

39. Three moles of an ideal gas ($C_v = 20 \text{ J/mol}\cdot\text{K}$) are heated by 15 K at constant volume. What is the change in internal energy?

- A. 900 J
- B. 450 J
- C. 1800 J
- D. 300 J

40. A closed system has its internal energy raised by 250 J while doing 350 J of work. How much heat was added?

- A. 100 J
- B. -100 J
- C. 250 J
- D. 600 J

41. Steam enters an adiabatic turbine at 3000 kJ/kg and leaves at 2700 kJ/kg, flowing at 10 kg/s. What is the shaft power?

- A. 300 kW
- B. 1500 kW
- C. 3000 kW
- D. 6000 kW

42. A refrigerator removes 750 W from the cold space while consuming 250 W of work. What is its coefficient of performance?

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

43. An equimolar liquid mixture of A (pure vapour pressure 110 kPa) and B (50 kPa) follows Raoult's law. What is the bubble-point pressure?

- A. 80 kPa
- B. 110 kPa
- C. 50 kPa
- D. 160 kPa

44. At the critical point of a pure substance:

- A. The substance freezes
- B. The liquid and vapour phases become indistinguishable
- C. The pressure drops to zero
- D. It sublimates directly

45. During a spontaneous process, the total entropy of an isolated system:

- A. Decreases
- B. Stays constant
- C. Becomes zero
- D. Increases

46. When most real gases expand through a throttle at constant enthalpy, their temperature usually:

- A. Drops
- B. Rises sharply
- C. Stays exactly constant
- D. Doubles

Material and Energy Balances

47. A 1500 kg/h feed is separated into a 600 kg/h product and a second product. What is the second product's flow rate?

- A. 2100 kg/h
- B. 600 kg/h
- C. 1500 kg/h
- D. 900 kg/h

48. An evaporator concentrates 2000 kg/h of a 5% solids feed to a 20% solids product. How much water is evaporated?

- A. 500 kg/h
- B. 100 kg/h
- C. 400 kg/h
- D. 1500 kg/h

49. Complete combustion of ethane follows $2\text{C}_2\text{H}_6 + 7\text{O}_2 \rightarrow 4\text{CO}_2 + 6\text{H}_2\text{O}$. How many moles of oxygen are needed for 2 mol of ethane?

- A. 5 mol
- B. 7 mol
- C. 3.5 mol

D. 14 mol

50. A 400 kg stream of 5% salt is mixed with a 100 kg stream of 30% salt. What is the salt content of the mixture?

A. 5%

B. 30%

C. 10%

D. 17.5%

51. A reactor is fed 800 mol of A, of which 200 mol leaves unreacted. What is the conversion?

A. 25%

B. 100%

C. 75%

D. 200 mol

52. A process recycles 300 mol/h and receives a fresh feed of 150 mol/h. What is the recycle ratio?

A. 0.5

B. 2

C. 450

D. 1

53. How much heat is required to raise 15 kg of water by 20 °C, with a specific heat of 4.18 kJ/kg·K?

A. 313 kJ

B. 627 kJ

C. 1254 kJ

D. 2508 kJ

54. A solid has a moisture content of 100% on a dry basis. What is the equivalent moisture content on a wet basis?

- A. 50%
- B. 100%
- C. 33%
- D. 200%

55. In the reaction $A \rightarrow 3B$, 5 mol of A reacts completely. How many moles of B are formed?

- A. 5 mol
- B. 15 mol
- C. 1.67 mol
- D. 8 mol

56. A burner needs 24 mol of oxygen stoichiometrically but is supplied with 30 mol. What is the percentage excess oxygen?

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

57. At steady state, the accumulation term in a material balance is:

- A. Maximum
- B. Equal to the input

- C. Zero
- D. Negative

Heat Transfer

58. A 0.05 m thick wall ($k = 3 \text{ W/m}\cdot\text{K}$, area 4 m^2) has a $25 \text{ }^\circ\text{C}$ temperature difference across it. What is the conductive heat rate?

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

59. A 3 m^2 surface transfers 900 W by convection with a temperature difference of $15 \text{ }^\circ\text{C}$. What is the convective heat-transfer coefficient?

- A. $60 \text{ W/m}^2\cdot\text{K}$
- B. $45 \text{ W/m}^2\cdot\text{K}$
- C. $20 \text{ W/m}^2\cdot\text{K}$
- D. $5 \text{ W/m}^2\cdot\text{K}$

60. The Stefan–Boltzmann law states that radiant emission is proportional to:

- A. The fourth power of absolute temperature
- B. The square of temperature
- C. Temperature directly
- D. The cube of temperature

61. In a counter-current exchanger, the hot stream cools from 100 °C to 70 °C while the cold stream warms from 30 °C to 50 °C. What is the log-mean temperature difference?

- A. 45 °C
- B. 44.8 °C
- C. 40 °C
- D. 50 °C

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

- A. 0.1 K/W
- B. 0.7 K/W
- C. 1.0 K/W
- D. 0.25 K/W

63. Two convective films, each 200 W/m²·K, act in series with negligible wall resistance. What is the overall coefficient U?

- A. 100 W/m²·K
- B. 200 W/m²·K
- C. 400 W/m²·K
- D. 50 W/m²·K

64. An exchanger has $U = 300 \text{ W/m}^2 \cdot \text{K}$, area 5 m², and a log-mean temperature difference of 20 °C. What is the heat duty?

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

D. 60 kW

65. The transfer of heat along a solid metal bar held at one hot end is by:

A. Convection

B. Radiation

C. Evaporation

D. Conduction

66. The critical radius of insulation is the radius at which adding more insulation to a small pipe:

A. Initially increases heat loss

B. Always reduces heat loss

C. Has no effect

D. Stops conduction entirely

Mass Transfer and Separation

67. A species diffuses through a 4 mm film with $D = 3 \times 10^{-9} \text{ m}^2/\text{s}$ and a concentration difference of 10 mol/m^3 . What is the molar flux?

A. $3 \times 10^{-5} \text{ mol/m}^2 \cdot \text{s}$

B. $7.5 \times 10^{-6} \text{ mol/m}^2 \cdot \text{s}$

C. $1.2 \times 10^{-5} \text{ mol/m}^2 \cdot \text{s}$

D. $7.5 \times 10^{-9} \text{ mol/m}^2 \cdot \text{s}$

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. 0.40
- C. 0.67
- D. 0.80

69. The minimum reflux ratio corresponds to a distillation column requiring:

- A. Infinite stages
- B. One stage
- C. Zero reflux
- D. Total reboil

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 98% of a solute, so $C_{in}/C_{out} = 50$. What is the number of transfer units, $NTU = \ln(C_{in}/C_{out})$?

- A. 0.98
- B. 50
- C. 2.0
- D. 3.9

72. According to Henry's law, the dissolved concentration of a gas in a liquid is proportional to its:

- A. Temperature
- B. Partial pressure
- C. Molar mass
- D. Viscosity

73. Increasing the reflux ratio improves product purity but increases:

- A. The number of components
- B. The feed flow alone
- C. The energy and condenser duty
- D. The relative volatility

74. The equilibrium moisture content of a solid depends on the surrounding air's:

- A. Velocity alone
- B. Pressure alone
- C. Relative humidity
- D. Colour

75. A mass-transfer coefficient k_c typically has units of:

- A. Metres per second
- B. Kilograms
- C. Pascals
- D. Dimensionless

Solids Handling

76. A 300 μm particle ($\Delta\rho = 1500 \text{ kg/m}^3$) settles in a fluid of viscosity $3 \times 10^{-3} \text{ Pa}\cdot\text{s}$. What is its Stokes' law terminal velocity?

- A. $1.2 \times 10^{-2} \text{ m/s}$
- B. $4.9 \times 10^{-2} \text{ m/s}$
- C. $2.45 \times 10^{-2} \text{ m/s}$
- D. $6.1 \times 10^{-3} \text{ m/s}$

77. A jaw crusher is used primarily for:

- A. Fine grinding to a powder
- B. Liquid filtration
- C. Gas absorption
- D. Coarse, primary size reduction of large lumps

78. Hindered settling occurs when:

- A. Particles are extremely dilute
- B. The particle concentration is high enough to interfere with individual settling
- C. The fluid is inviscid
- D. The particles dissolve

79. The Hausner ratio is used to assess a powder's:

- A. Solubility
- B. Flowability
- C. Colour

D. Melting point

Chemical Reaction Engineering

80. A first-order reaction ($k = 0.2 \text{ min}^{-1}$) starts at 10 mol/L . What is the concentration after 5 minutes, using $C = C_0 e^{-kt}$?

- A. 3.68 mol/L
- B. 2.0 mol/L
- C. 5.0 mol/L
- D. 0.37 mol/L

81. A first-order reaction ($k = 0.1 \text{ min}^{-1}$) runs in a PFR with a space time of 10 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 ($k = 0.5 \text{ min}^{-1}$) reaches 90% conversion in a CSTR. What space time is required?

- A. 9 min
- B. 4.5 min
- C. 36 min
- D. 18 min

83. A first-order reaction has a rate constant of 0.0462 min^{-1} . What is its half-life, $t_{1/2} = 0.693/k$?

- A. 30 min
- B. 60 min
- C. 7.5 min
- D. 15 min

84. A first-order reaction has a half-life that is:

- A. Independent of the initial concentration
- B. Proportional to the concentration
- C. Inversely proportional to the concentration
- D. Always one minute

85. For the reversible reaction $A \rightleftharpoons B$, the forward rate constant is 10 and the reverse is 2.5. What is the equilibrium constant?

- A. 12.5
- B. 25
- C. 0.25
- D. 4

86. A reaction with a high activation energy is:

- A. Insensitive to temperature
- B. Always zero order
- C. Very sensitive to temperature changes
- D. Independent of catalysts

Engineering Economics

87. What is the future worth of \$15,000 invested for 4 years at 6% interest ($1.06^4 = 1.2625$)?

- A. \$16,800
- B. \$18,937
- C. \$20,400
- D. \$22,500

88. What is the present worth of \$40,000 to be received in 5 years at 5% interest ($1.05^5 = 1.2763$)?

- A. \$31,341
- B. \$36,000
- C. \$40,000
- D. \$51,051

89. An \$80,000 asset with an \$8,000 salvage value is depreciated straight-line over 4 years. What is the annual depreciation?

- A. \$20,000
- B. \$16,000
- C. \$18,000
- D. \$72,000

90. A \$150,000 investment yields an annual profit of \$30,000. What is the simple return on investment?

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

D. 2%

Process Design

91. The correct order of increasing detail among process diagrams is:

- A. P&ID → process flow diagram → block flow diagram
- B. Process flow diagram → block flow diagram → P&ID
- C. P&ID → block flow diagram → process flow diagram
- D. Block flow diagram → process flow diagram → P&ID

92. A column separating a feed into more than two products of differing purity may use:

- A. A single condenser alone
- B. No reboiler at all
- C. Zero theoretical stages
- D. A side draw or multiple columns

93. Equipment that cost \$200,000 at a cost index of 600 is re-estimated at a current index of 900. What is the updated cost?

- A. \$300,000
- B. \$133,333
- C. \$200,000
- D. \$400,000

94. A shell-and-tube exchanger is preferred over a plate exchanger when:

- A. The area must be minimal

- B. Only gentle duties apply
- C. High pressure and temperature must be handled
- D. Cleaning is never needed

95. The operating point of a centrifugal pump occurs where:

- A. The pump curve intersects the system curve
- B. The head is zero
- C. The flow is always at its maximum
- D. The efficiency is zero

96. A material commonly used for high-temperature furnace linings is:

- A. PVC
- B. Aluminium
- C. Rubber
- D. Refractory brick

97. The most economic insulation thickness minimises the sum of:

- A. Insulation cost and the cost of heat lost
- B. Pump cost and valve cost
- C. Labour and land cost
- D. Catalyst and feed cost

Process Control

98. The controller action that responds to the accumulated past error is:

- A. Proportional action
- B. Integral action
- C. Derivative action
- D. On–off action

99. A capacitance level sensor detects liquid level through a change in:

- A. Fluid colour
- B. Electrical capacitance between its probes
- C. Flow rate
- D. Temperature

100. An equal-percentage control valve gives equal percentage changes in flow for:

- A. Equal increments of valve travel
- B. Zero travel
- C. Constant pressure only
- D. Any fluid density

101. The Ziegler–Nichols method tunes a controller using the:

- A. Fluid density and viscosity
- B. Pipe length and diameter
- C. Ultimate gain and oscillation period
- D. Ambient temperature

Safety, Health, and Environment

102. The route of entry most relevant for airborne vapours is:

- A. Ingestion
- B. Inhalation
- C. Injection
- D. Absorption through intact skin alone

103. A relief valve's set pressure should be:

- A. Well above the design pressure
- B. Equal to the operating pressure
- C. Unrelated to the vessel rating
- D. At or below the vessel's maximum allowable working pressure

104. A Class B fire involves:

- A. Ordinary combustibles
- B. Electrical equipment
- C. Metals
- D. Flammable liquids and gases

105. Dilution ventilation controls airborne contaminants by:

- A. Capturing them at the source
- B. Heating the contaminant
- C. Mixing in clean air to reduce the concentration

D. Compressing the air

106. Acid rain is caused chiefly by emissions of:

A. Carbon dioxide alone

B. Methane

C. Sulphur and nitrogen oxides

D. Ozone

Ethics and Professional Practice

107. An engineer asked to approve work that violates a safety code should:

A. Approve it to keep the client

B. Refuse and document the objection

C. Approve it quietly

D. Resign without explanation

108. When an engineer's personal financial interest could affect professional judgement, they must:

A. Keep it private

B. Exaggerate the benefits

C. Withdraw all opinions

D. Disclose it to all affected parties

109. Signing off on test results that were never actually performed is:

A. Acceptable under deadline pressure

- B. Falsification and a serious ethical violation
- C. Standard industry practice
- D. Permitted if the results seem plausible

110. An engineer's responsibility toward the environment includes:

- A. Only the construction cost
- B. Considering the full life-cycle impact of a design
- C. Ignoring waste streams
- D. Maximising raw-material use

Practice Exam 17 – Answer Key and Explanations

1. **B** — Separating $dy/dx = 3y$ gives $y = Ce^{(3x)}$, and applying $y(0) = 2$ fixes $C = 2$, so $y = 2e^{(3x)}$. The positive exponent reflects growth proportional to the current value.
2. **C** — The antiderivative of $e^{(2x)}$ is $\frac{1}{2}e^{(2x)}$, evaluated from 0 to 1 as $\frac{1}{2}(e^2 - 1) = \frac{1}{2}(6.39) = 3.19$. The factor of one-half comes from the chain rule on the exponent.
3. **A** — Multiplying a matrix by its inverse yields the identity matrix, the matrix analogue of multiplying a number by its reciprocal to get one. This defines what the inverse means.
4. **B** — The derivative of $\cos(x)$ is $-\sin(x)$. The negative sign reflects that the cosine is decreasing where the sine is positive.
5. **A** — Using the expansion $(1 - \cos x) \approx x^2/2$, the limit equals $1/2$. This standard result appears in linearising oscillatory systems.
6. **D** — The magnitude is $\sqrt{(6^2 + 8^2)} = \sqrt{100} = 10$. The Pythagorean form gives the length of a two-component vector.
7. **D** — Only one of the 36 equally likely outcomes gives a sum of 2 (a pair of ones), so the probability is $1/36 = 0.028$. It is the least likely two-dice total.
8. **C** — The mean is the sum over the count, $(10 + 20 + 30 + 40)/4 = 100/4 = 25$. The mean is the data's balance point.
9. **D** — The number of combinations is $C(7,2) = 7!/(2!5!) = 21$. Combinations count unordered selections.

- 10. B** — For mutually exclusive events, which cannot occur together, $P(A \text{ or } B) = P(A) + P(B)$. The probabilities simply add because there is no overlap to subtract.
- 11. D** — Binomial variance is $np(1 - p) = 100 \times 0.5 \times 0.5 = 25$. The spread is greatest when p is near one-half.
- 12. C** — Power is work over time, $600/4 = 150 \text{ W}$. Power measures the rate at which work is done.
- 13. C** — Two equal resistors in parallel give half the value, $10/2 = 5 \Omega$. The parallel result is always less than either individual resistor.
- 14. D** — Momentum is mass times velocity, $12 \times 5 = 60 \text{ kg}\cdot\text{m/s}$. This quantity is conserved in collisions absent external forces.
- 15. B** — Power dissipated is $I^2R = 2^2 \times 8 = 32 \text{ W}$. This resistive heating sets conductor sizing and cooling needs.
- 16. C** — Resilience is the capacity to absorb energy elastically and release it on unloading, measured by the area under the elastic part of the stress–strain curve. It governs a material's springiness within the elastic range.
- 17. D** — Engineering stress is the applied force divided by the original cross-sectional area. Using the original area distinguishes it from true stress, which uses the instantaneous area.
- 18. B** — Normalising heats steel above its transformation range and then cools it in still air, refining the grain structure and improving uniformity. The faster air cooling gives finer grains than furnace annealing.
- 19. A** — Galvanising coats steel with zinc, which is more active and corrodes sacrificially in place of the steel even where the coating is scratched. This cathodic protection is why galvanised steel resists rust so well.
- 20. C** — Increasing cross-linking ties polymer chains together more tightly, raising rigidity and reducing flexibility. Heavily cross-linked polymers become hard, infusible thermosets.
- 21. A** — With $[H^+] = 10^{-3}$, the pH is $-\log(10^{-3}) = 3$. This value is acidic, well below neutral.
- 22. B** — Summing atomic masses, $N (14) + 2O (32) = 46 \text{ g/mol}$. Molar mass converts between mass and moles in stoichiometry.
- 23. D** — By Boyle's law at constant temperature, tripling the pressure reduces the volume to one-third, so 9 L becomes 3 L. Pressure and volume vary inversely.
- 24. A** — Lowering the temperature of an exothermic reaction shifts the equilibrium toward the products, since the system favours releasing heat. By Le Chatelier's principle, removing heat drives the heat-releasing direction.

- 25. B** — The one-to-two stoichiometry gives two moles of nitric oxide per mole of nitrogen, so 3 mol of nitrogen yields 6 mol. Nitrogen is the limiting reactant with oxygen in excess.
- 26. C** — Sodium carries an oxidation state of +1 in sodium chloride, having lost one electron to chlorine. Group 1 metals consistently show a +1 state in their compounds.
- 27. A** — A buffer resists pH change when small amounts of acid or base are added, because its weak-acid/conjugate-base pair neutralises the addition. This stabilising action is vital in biological and chemical systems.
- 28. B** — Transpiration is the release of water vapour from plant leaves, mainly through the stomata. It drives the upward movement of water from the roots through the plant.
- 29. D** — Reynolds number is $\rho vD/\mu = (900 \times 1 \times 0.04)/0.009 = 4000$. This value lies just into the turbulent regime.
- 30. A** — Continuity gives $v_2 = v_1 A_1/A_2 = 8 \times (0.02/0.08) = 2$ m/s. The fourfold area increase reduces the velocity to a quarter.
- 31. B** — A pitot tube measures velocity from the difference between the stagnation pressure at its tip and the static pressure, by Bernoulli's equation. This pressure difference converts directly into a velocity reading.
- 32. D** — Hydrostatic pressure is $\rho gh = 1000 \times 9.81 \times 5 = 49,050$ Pa ≈ 49.1 kPa. Pressure rises linearly with depth.
- 33. D** — For laminar flow, the friction factor is $64/Re = 64/80 = 0.8$. The inverse dependence on Reynolds number gives high friction at low flow.
- 34. A** — Ideal hydraulic power is $\rho gQH = 1000 \times 9.81 \times 0.03 \times 20 = 5886$ W ≈ 5.89 kW. Dividing by efficiency would give the shaft power.
- 35. B** — Velocity is flow over area, $0.6/0.15 = 4$ m/s. This follows directly from the continuity equation.
- 36. C** — The Darcy equation gives $h_f = f(L/D)(v^2/2g) = 0.03 \times (50/0.1) \times (9/19.62) = 6.88$ m. Friction head loss scales with the square of velocity.
- 37. B** — A Newtonian fluid is one whose shear stress is directly proportional to the shear rate, the constant of proportionality being the viscosity. Water and air behave this way, unlike shear-thinning or shear-thickening fluids.
- 38. A** — Carnot efficiency is $1 - T_c/T_h = 1 - 375/750 = 0.50$, or 50%. The temperature ratio alone fixes this ceiling.
- 39. A** — Internal energy change at constant volume is $nC_v\Delta T = 3 \times 20 \times 15 = 900$ J. The constant-volume heat capacity applies because no work is done.

- 40. D** — The first law gives $Q = \Delta U + W = 250 + 350 = 600$ J. Heat supplied both raises internal energy and does work.
- 41. C** — Adiabatic turbine power is $\dot{m}(h_1 - h_2) = 10 \times (3000 - 2700) = 3000$ kW. The enthalpy drop converts directly into shaft work.
- 42. A** — Refrigerator COP is $Q_c/W = 750/250 = 3.0$. 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 $0.5 \times 110 + 0.5 \times 50 = 80$ kPa. The total pressure is the mole-fraction-weighted sum of the pure vapour pressures.
- 44. B** — At the critical point, the densities of the liquid and vapour become equal and the two phases become indistinguishable. Above it, no amount of pressure will liquefy the gas.
- 45. D** — During a spontaneous process, the total entropy of an isolated system increases, by the second law of thermodynamics. This entropy increase sets the direction of natural change.
- 46. A** — For most real gases below their inversion temperature, throttling at constant enthalpy produces a temperature drop, the Joule–Thomson effect. This cooling is exploited in gas liquefaction and refrigeration.
- 47. D** — A steady-state mass balance gives the second product as $1500 - 600 = 900$ kg/h. Conservation of mass closes the separation.
- 48. D** — A solids balance gives $0.05 \times 2000 = 0.20 \times L$, so the product is $L = 500$ kg/h, and water evaporated = $2000 - 500 = 1500$ kg/h. The non-volatile solids fix the product rate.
- 49. B** — At seven moles of oxygen per two of ethane, 2 mol of ethane needs 7 mol. Combustion stoichiometry sets the oxygen demand.
- 50. C** — The combined salt is $0.05 \times 400 + 0.30 \times 100 = 20 + 30 = 50$ kg in 500 kg, giving 10%. A component balance yields the blended composition.
- 51. C** — Conversion is $(800 - 200)/800 = 75\%$. This fraction measures how completely the feed is consumed.
- 52. B** — The recycle ratio is recycle over fresh feed, $300/150 = 2$. It characterises the process's reliance on recycling.
- 53. C** — Sensible heat is $mC_p\Delta T = 15 \times 4.18 \times 20 = 1254$ kJ. This relation sizes the heating duty for a temperature change.
- 54. A** — Converting 100% dry basis gives wet basis = $100/(100 + 100) = 50\%$. At this level the water and dry solid are present in equal mass.

- 55. B** — The stoichiometry produces three moles of B per mole of A, so 5 mol of A yields 15 mol of B. Reaction stoichiometry converts reactant consumed into product formed.
- 56. A** — Percentage excess is $(30 - 24)/24 = 25\%$. The surplus oxygen ensures complete combustion.
- 57. C** — At steady state, no quantity accumulates within the system, so the accumulation term is zero and input equals output. This simplification underlies most continuous-process balances.
- 58. D** — Fourier's law gives $Q = kA\Delta T/L = (3 \times 4 \times 25)/0.05 = 6000 \text{ W}$. Conductive heat rate scales with conductivity, area, and driving temperature.
- 59. C** — Rearranging $Q = hA\Delta T$ gives $h = 900/(3 \times 15) = 20 \text{ W/m}^2\cdot\text{K}$. The coefficient measures how effectively the fluid removes heat.
- 60. A** — The Stefan–Boltzmann law states that a body's radiant emission is proportional to the fourth power of its absolute temperature. This strong dependence makes radiation dominate at high temperatures.
- 61. B** — With $\Delta T_1 = 100 - 50 = 50 \text{ }^\circ\text{C}$ and $\Delta T_2 = 70 - 30 = 40 \text{ }^\circ\text{C}$, the log-mean is $(50 - 40)/\ln(50/40) = 44.8 \text{ }^\circ\text{C}$. The LMTD is the correct mean driving force, just below the arithmetic mean of $45 \text{ }^\circ\text{C}$.
- 62. B** — Series thermal resistances add directly, $0.2 + 0.5 = 0.7 \text{ K/W}$. The thermal-circuit analogy makes composite-wall analysis straightforward.
- 63. A** — With negligible wall resistance, $1/U = 1/200 + 1/200 = 0.01$, so $U = 100 \text{ W/m}^2\cdot\text{K}$. Two equal series films halve the overall coefficient.
- 64. C** — Exchanger duty is $UA\Delta T = 300 \times 5 \times 20 = 30,000 \text{ W} = 30 \text{ kW}$. This product of coefficient, area, and driving force sizes the exchanger.
- 65. D** — Heat travelling along a solid metal bar from a hot end is transferred by conduction, the diffusion of energy through the lattice and free electrons. No bulk movement of material occurs.
- 66. A** — Below the critical radius, adding insulation to a small pipe or wire actually increases heat loss, because the added outer surface area outweighs the added resistance. Beyond the critical radius, further insulation reduces loss as expected.
- 67. B** — Fick's law gives flux $= D \cdot \Delta C / \delta = (3 \times 10^{-9} \times 10) / (4 \times 10^{-3}) = 7.5 \times 10^{-6} \text{ mol/m}^2\cdot\text{s}$. Flux rises with diffusivity and concentration difference and falls with film thickness.
- 68. C** — Using $y = \alpha x / [1 + (\alpha - 1)x] = (2 \times 0.5) / (1 + 0.5) = 1.0 / 1.5 = 0.67$. The vapour is enriched in the volatile component relative to the liquid.
- 69. A** — At the minimum reflux ratio, the operating and equilibrium lines pinch, so the column would need an infinite number of stages. Real columns operate above this limiting reflux.

- 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 $\ln(C_{in}/C_{out}) = \ln(50) \approx 3.9$. NTU rises with the fractional removal demanded.
- 72. B** — Henry's law states that the dissolved concentration of a gas is proportional to its partial pressure above the liquid. This relation governs how much gas an absorber can dissolve.
- 73. C** — Raising the reflux ratio improves product purity but increases the reboiler and condenser duty, since more vapour and liquid are circulated. This raises the column's energy cost.
- 74. C** — The equilibrium moisture content of a hygroscopic solid is set by the relative humidity of the surrounding air. A solid dried in humid air retains more equilibrium moisture.
- 75. A** — A mass-transfer coefficient k_c has units of metres per second, expressing a flux per unit concentration difference. These velocity-like units reflect the rate of transfer across the interface.
- 76. C** — Stokes' law gives $v = gd^2\Delta\rho/(18\mu) = (9.81 \times (3 \times 10^{-4})^2 \times 1500)/(18 \times 3 \times 10^{-3}) = 2.45 \times 10^{-2}$ m/s. The square dependence on diameter makes settling highly size-sensitive.
- 77. D** — A jaw crusher performs coarse, primary size reduction, breaking large lumps between two jaws. Fine grinding is left to downstream mills.
- 78. B** — Hindered settling occurs when the particle concentration is high enough that neighbouring particles interfere with one another's motion, slowing the settling. The upward displaced fluid retards each particle.
- 79. B** — The Hausner ratio, the tapped density over the bulk density, is used to assess a powder's flowability. A higher ratio indicates poorer flow.
- 80. A** — First-order decay gives $C = C_0e^{(-kt)} = 10 \times e^{(-0.2 \times 5)} = 10 \times e^{(-1)} = 10 \times 0.368 = 3.68$ mol/L. The concentration falls exponentially at a rate fixed by k .
- 81. C** — For a first-order PFR, conversion is $X = 1 - e^{(-k\tau)} = 1 - e^{(-0.1 \times 10)} = 1 - e^{(-1)} = 0.63$. This conversion is reached at a space time of one time constant.
- 82. D** — For a first-order CSTR, $\tau = X/[k(1 - X)] = 0.9/(0.5 \times 0.1) = 18$ min. High conversion in a CSTR demands a long residence time because it operates at the low exit concentration.
- 83. D** — The first-order half-life is $0.693/k = 0.693/0.0462 = 15$ min. This half-life is independent of concentration, the signature of first-order kinetics.
- 84. A** — A first-order reaction has a half-life independent of the initial concentration, equal to $0.693/k$. This constant half-life is a diagnostic feature of first-order behaviour.

- 85. D** — At equilibrium the forward and reverse rates balance, so $K = k_{\text{forward}}/k_{\text{reverse}} = 10/2.5 = 4$. This links the kinetic constants to the equilibrium position.
- 86. C** — A high activation energy makes the rate constant very sensitive to temperature, since the Arrhenius exponential changes sharply. Such reactions speed up dramatically with modest heating.
- 87. B** — Future worth is $P(1 + i)^n = 15,000 \times 1.06^4 = 15,000 \times 1.2625 = \$18,937$. Compounding grows the sum forward at the stated rate.
- 88. A** — Present worth is $F/(1 + i)^n = 40,000/1.05^5 = 40,000/1.2763 = \$31,341$. Discounting reflects that a future sum is worth less today.
- 89. C** — Straight-line depreciation is $(80,000 - 8,000)/4 = \$18,000$ per year. This even allocation spreads the depreciable basis across the service life.
- 90. A** — Return on investment is annual profit over investment, $30,000/150,000 = 20\%$. It expresses the yearly earnings as a fraction of the capital committed.
- 91. D** — The diagrams increase in detail from the block flow diagram, through the process flow diagram, to the P&ID. Each adds more information, ending with full instrumentation and control detail.
- 92. D** — Separating a feed into more than two products of differing purity requires a side draw from a single column or a sequence of multiple columns. A simple two-product column cannot deliver three or more cuts.
- 93. A** — Updating with the cost index gives $200,000 \times (900/600) = \$300,000$. The index ratio corrects the historical cost for inflation.
- 94. C** — A shell-and-tube exchanger is preferred for high-pressure and high-temperature duties, which its robust construction handles better than gasketed plate units. Plate exchangers excel at compactness but are limited in pressure and temperature.
- 95. A** — A centrifugal pump operates where its head–flow curve intersects the system resistance curve, balancing supplied head against demand. This intersection sets the actual delivered flow.
- 96. D** — Refractory brick withstands the very high temperatures of furnace linings, resisting heat and chemical attack. Plastics, aluminium, and rubber would fail at such temperatures.
- 97. A** — The economic insulation thickness minimises the combined annual cost of the insulation itself and the value of the heat it fails to retain. Adding insulation reduces heat loss but raises capital cost, giving an optimum.
- 98. B** — Integral control action responds to the accumulated past error, continuing to adjust until that error is driven to zero. It thereby removes the steady-state offset left by proportional action.

- 99. B** — A capacitance level sensor detects liquid level from the change in electrical capacitance between its probes as the dielectric medium changes. It suits a range of liquids and bulk solids.
- 100. A** — An equal-percentage valve gives equal percentage changes in flow for equal increments of stem travel. This characteristic provides fine control at low flows and is widely used for throttling.
- 101. C** — The Ziegler–Nichols method tunes a controller from the ultimate gain at which the loop just oscillates and the period of that oscillation. These two measured values set the recommended controller settings.
- 102. B** — For airborne vapours, inhalation is the primary route of entry into the body, as the vapour is breathed directly into the lungs. This is why exposure limits and respiratory protection focus on inhalation.
- 103. D** — A relief valve's set pressure must be at or below the vessel's maximum allowable working pressure, so it opens before that limit is exceeded. Setting it higher would allow the vessel to be overpressured.
- 104. D** — A Class B fire involves flammable liquids and gases, requiring extinguishing agents that smother or interrupt the flame. Knowing the fire class dictates the correct extinguisher.
- 105. C** — Dilution ventilation reduces airborne contaminant concentration by mixing in clean air throughout the space. It is less effective than capturing a contaminant at its source but suits low-toxicity, dispersed releases.
- 106. C** — Acid rain results chiefly from emissions of sulphur and nitrogen oxides, which form sulphuric and nitric acids in the atmosphere. Controlling these emissions is central to limiting acid deposition.
- 107. B** — An engineer asked to approve work that violates a safety code must refuse and document the objection, since approval would endanger the public. Recording the objection protects both the public and the engineer.
- 108. D** — When a personal financial interest could affect professional judgement, the engineer must disclose it to all affected parties. Disclosure preserves trust and lets others weigh the potential bias.
- 109. B** — Signing off on tests that were never performed is falsification, a serious ethical and often legal violation. Such fabrication undermines safety and the integrity of the profession.
- 110. B** — An engineer's environmental responsibility includes considering the full life-cycle impact of a design, from raw materials through use to disposal. This whole-life view is essential to sustainable practice.