

PRACTICE EXAM 7: FE CHEMICAL SIMULATION (110 QUESTIONS)

Mathematics

1. What is the general solution of the differential equation $y'' - 4y' + 4y = 0$?

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

B. $y = C_1\cos(2x) + C_2\sin(2x)$

C. $y = (C_1 + C_2x)e^{(2x)}$

D. $y = C_1e^{(4x)} + C_2e^{(-x)}$

2. Evaluate the definite integral of $\cos(x)$ from $x = 0$ to $x = \pi/2$.

A. 1

B. 0

C. $\pi/2$

D. -1

3. A homogeneous linear system $Ax = 0$ possesses non-trivial solutions under which condition?

A. $\det A$ is greater than zero

B. $\det A$ equals one

C. $\det A$ equals zero

D. A is the identity matrix

4. Using the trapezoidal rule with a step size of 1, estimate the integral of f from $x = 0$ to $x = 2$, given $f(0) = 1$, $f(1) = 3$, and $f(2) = 5$.

- A. 4
- B. 6
- C. 9
- D. 5

5. Using Euler's identity, what is the value of $e^{i\pi}$?

- A. 1
- B. -1
- C. i
- D. 0

6. For the function $f = x^2y^3$, what is the mixed second partial derivative $\partial^2 f / \partial x \partial y$?

- A. $6xy^2$
- B. $2xy^3$
- C. $6x^2y^2$
- D. $2x$

Probability and Statistics

7. Machine 1 makes 60% of output with a 2% defect rate, and Machine 2 makes 40% with a 5% defect rate. What is the overall defect rate?

- A. 2.0%
- B. 5.0%

- C. 3.2%
- D. 7.0%

8. A population has a standard deviation of 10. What is the standard error of the mean for samples of size 25?

- A. 10
- B. 0.4
- C. 5
- D. 2

9. In how many ways can 2 items be chosen from a set of 6 distinct items, where order does not matter?

- A. 15
- B. 30
- C. 12
- D. 720

10. What is the expected value of the sum of two fair six-sided dice?

- A. 6
- B. 6.5
- C. 12
- D. 7

11. Two identical components, each working with probability 0.9, are placed in parallel so the system fails only if both fail. What is the probability the system works?

- A. 0.90

- B. 0.99
- C. 0.81
- D. 0.18

Engineering Sciences

12. A constant force of 50 N moves an object at a steady velocity of 4 m/s in the direction of the force. What power is delivered?

- A. 12.5 W
- B. 54 W
- C. 200 W
- D. 46 W

13. A 2 F capacitor is charged to 10 V. How much energy is stored, using $E = \frac{1}{2}CV^2$?

- A. 200 J
- B. 20 J
- C. 10 J
- D. 100 J

14. A block rests on a surface with a coefficient of friction of 0.3 and a normal force of 200 N. What is the maximum friction force?

- A. 600 N
- B. 60 N
- C. 0.0015 N
- D. 30 N

15. A gas expands at a constant pressure of 100 kPa through a volume change of 0.02 m³. How much work does it do?

- A. 5000 J
- B. 200 J
- C. 100 J
- D. 2000 J

Materials Science

16. Young's modulus of a material is a direct measure of its:

- A. Stiffness
- B. Hardness
- C. Toughness
- D. Density

17. The progressive failure of a component under repeated cyclic loading, even below its ultimate strength, is known as:

- A. Creep
- B. Corrosion
- C. Yielding
- D. Fatigue

18. Slow, time-dependent deformation of a material under constant load at elevated temperature is called:

- A. Fatigue
- B. Creep

- C. Fracture
- D. Annealing

19. What distinguishes a thermoplastic from a thermoset?

- A. It can be remelted and reshaped repeatedly
- B. It cannot be melted once it is formed
- C. It is always fully crystalline
- D. It has covalent cross-links throughout

20. Adding a small amount of carbon to iron to make steel primarily increases its:

- A. Strength and hardness
- B. Electrical conductivity
- C. Corrosion resistance
- D. Thermal expansion

Chemistry and Biology

21. An aqueous solution at 25 °C has a pH of 4. What is its pOH?

- A. 4
- B. 14
- C. 10
- D. 7

22. A compound is 40% carbon, 6.7% hydrogen, and 53.3% oxygen by mass. What is its empirical formula?

- A. C₂H₄O
- B. CH₂O
- C. CHO
- D. C₂H₆O

23. What volume does one mole of an ideal gas occupy at standard temperature and pressure (0 °C, 1 atm)?

- A. 1 L
- B. 24.5 L
- C. 18 L
- D. 22.4 L

24. What volume of 0.1 M NaOH is needed to neutralise 50 mL of 0.1 M HCl?

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

25. For $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$, what is the effect of increasing the total pressure?

- A. Equilibrium shifts toward products, the side with fewer gas moles
- B. Equilibrium shifts toward reactants, the side with more gas moles
- C. There is no shift in either direction
- D. Equilibrium shifts toward products, the side with more gas moles

26. Genetic information in DNA is encoded using a sequence drawn from how many distinct building blocks?

- A. Twenty amino acids
- B. Four nucleotide bases
- C. Two sugars
- D. Three lipids

27. In a redox reaction, the species that loses electrons is correctly described as:

- A. Reduced, and it acts as the oxidising agent
- B. Unchanged in its oxidation state
- C. Oxidised, and it acts as the reducing agent
- D. Always the metal cation present

28. What is the concentration in parts per million of 5 mg of a solute dissolved in 1 kg of water?

- A. 0.5 ppm
- B. 5 ppm
- C. 50 ppm
- D. 5000 ppm

Fluid Mechanics

29. A fluid (density 800 kg/m^3 , viscosity $2 \times 10^{-3} \text{ Pa}\cdot\text{s}$) flows at 1.5 m/s through a 0.1 m pipe. What is the Reynolds number?

- A. 600
- B. 6000
- C. 12000
- D. 60000

30. Water flows at 4 m/s through a 0.08 m² duct that then expands to 0.16 m². What is the velocity in the larger section?

- A. 8 m/s
- B. 2 m/s
- C. 4 m/s
- D. 1 m/s

31. Water (density 1000 kg/m³) moves at 10 m/s. What is the dynamic (velocity) pressure, $\frac{1}{2}\rho v^2$?

- A. 50 kPa
- B. 100 kPa
- C. 5 kPa
- D. 10 kPa

32. In fully turbulent flow at high Reynolds number, the friction factor depends mainly on which property?

- A. The velocity only
- B. The viscosity only
- C. The pipe length
- D. The relative pipe roughness

33. A pump delivers 0.02 m³/s of water against a head of 15 m at 75% efficiency. What shaft power is required?

- A. 2.94 kW
- B. 1.96 kW
- C. 3.92 kW
- D. 5.89 kW

34. A gauge reads 150 kPa where the atmospheric pressure is 101 kPa. What is the absolute pressure?

- A. 49 kPa
- B. 150 kPa
- C. 251 kPa
- D. 101 kPa

35. A venturi meter determines the flow rate of a fluid by relating it to which measured quantity?

- A. The temperature rise across the meter
- B. The change in fluid density
- C. The fluid viscosity
- D. The pressure drop across the throat

36. A floating body is in equilibrium when the buoyant force acting on it equals:

- A. Its own weight
- B. Zero
- C. The entire weight of the fluid
- D. The atmospheric pressure

37. For several pipe segments connected in series, the total head loss equals:

- A. The largest single segment loss
- B. The sum of the individual losses
- C. The average of the losses
- D. Zero

Thermodynamics

38. A Carnot engine operates between reservoirs at 500 K and 300 K. What is its maximum efficiency?
- A. 60%
 - B. 40%
 - C. 50%
 - D. 20%
39. Three moles of an ideal gas ($C_v = 20 \text{ J/mol}\cdot\text{K}$) are heated by $25 \text{ }^\circ\text{C}$ at constant volume. What is the change in internal energy?
- A. 1500 J
 - B. 750 J
 - C. 3000 J
 - D. 60 J
40. A heat engine receives 1000 J of heat and operates at 30% thermal efficiency. How much work does it produce?
- A. 700 J
 - B. 1000 J
 - C. 300 J
 - D. 3333 J
41. For any irreversible process, what is the sign of the total entropy change of the system plus its surroundings?
- A. Negative

- B. Zero
- C. Constant
- D. Positive

42. The dew point of a vapour mixture is the temperature at which it first:

- A. Fully evaporates
- B. Begins to condense
- C. Reaches its critical point
- D. Becomes an ideal gas

43. Fugacity is best understood as:

- A. An effective temperature
- B. A molar volume term
- C. An entropy correction
- D. An effective pressure accounting for non-ideality

44. Most real gases cool when throttled below their inversion temperature because:

- A. The Joule–Thomson coefficient is positive
- B. Enthalpy increases during throttling
- C. Work is done on the gas
- D. The gas behaves as an ideal gas

45. In a Rankine cycle, in what state does the working fluid enter the pump before the boiler?

- A. As a superheated vapour

- B. As a two-phase mixture
- C. As a liquid
- D. As a supercritical gas

46. For an ideal solution, what is the value of the enthalpy of mixing?

- A. Positive
- B. Negative
- C. Maximum
- D. Zero

Material and Energy Balances

47. When unreacted feed is recycled to a reactor, how does the overall conversion compare with the single-pass conversion?

- A. It is lower than the single-pass conversion
- B. It is equal to the single-pass conversion
- C. It is higher than the single-pass conversion
- D. It is unrelated to the single-pass conversion

48. A wet solid weighing 100 kg at 50% moisture loses 40 kg of water in a dryer. What is the moisture content of the dried product?

- A. 50%
- B. 16.7%
- C. 10%
- D. 40%

49. Complete combustion of carbon follows $C + O_2 \rightarrow CO_2$. How much carbon dioxide forms from 12 kg of carbon?

- A. 44 kg
- B. 12 kg
- C. 32 kg
- D. 28 kg

50. Two 100 kg/h streams, one with 10% salt and one with 30% salt, are mixed. What is the salt concentration of the combined stream?

- A. 40%
- B. 20%
- C. 30%
- D. 10%

51. A reactor converts A into 50 mol of desired product B and 25 mol of by-product C. What is the selectivity of B relative to C?

- A. 0.5
- B. 2
- C. 75
- D. 25

52. What is the primary purpose of a purge stream in a recycle loop?

- A. To reduce heat loss from the system
- B. To relieve pressure caused by reaction
- C. To prevent catalyst poisoning by the product

D. To prevent the build-up of inert material in the recycle

53. An adiabatic reactor running an exothermic reaction shows a rising temperature because:

A. The reaction heat is retained with no removal

B. Heat is added from the surroundings

C. The reaction is actually endothermic

D. Work is being done on the system

54. A double-effect evaporator achieves energy savings chiefly by:

A. Operating both effects at the same pressure

B. Using the vapour of one effect to heat the next

C. Condensing all vapour to liquid first

D. Adding fresh steam equally to each effect

55. A burner requires 4 mol of oxygen stoichiometrically but is supplied with 5 mol. What is the percentage excess oxygen?

A. 20%

B. 80%

C. 25%

D. 100%

56. In a material balance, a component that passes through a unit unchanged is conveniently used as a:

A. Limiting reactant

B. Basis of zero

C. Recycle stream

D. Tie component

57. A mixture is 50% by mass of A (molar mass 20) and 50% of B (molar mass 80). What is the mole fraction of A?

- A. 0.50
- B. 0.80
- C. 0.20
- D. 0.625

Heat Transfer

58. A 0.05 m thick wall ($k = 15 \text{ W/m}\cdot\text{K}$, area 2 m^2) has a $50 \text{ }^\circ\text{C}$ temperature difference across it. What is the conductive heat rate?

- A. 3 kW
- B. 15 kW
- C. 1.5 kW
- D. 30 kW

59. A surface of area 4 m^2 transfers 2000 W by convection with a temperature difference of $25 \text{ }^\circ\text{C}$. What is the convective heat-transfer coefficient?

- A. $200 \text{ W/m}^2\cdot\text{K}$
- B. $100 \text{ W/m}^2\cdot\text{K}$
- C. $20 \text{ W/m}^2\cdot\text{K}$
- D. $80 \text{ W/m}^2\cdot\text{K}$

60. What is the emissivity of an ideal black body?

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

61. In an exchanger where both terminal temperature differences are $20\text{ }^{\circ}\text{C}$, what is the log-mean temperature difference?

- A. $20\text{ }^{\circ}\text{C}$
- B. $0\text{ }^{\circ}\text{C}$
- C. $40\text{ }^{\circ}\text{C}$
- D. $10\text{ }^{\circ}\text{C}$

62. Doubling the thickness of insulation on a flat wall, with all else constant, has what effect on the conductive heat loss?

- A. It doubles the heat loss
- B. It quadruples the heat loss
- C. It has no effect
- D. It roughly halves the heat loss

63. How do boiling heat-transfer coefficients typically compare with single-phase natural-convection coefficients?

- A. They are lower than conduction
- B. They are much higher than single-phase natural convection
- C. They are equal to radiation
- D. They are effectively zero

64. What is the effect of fouling deposits on a heat-exchanger surface?

- A. They reduce the overall heat-transfer coefficient
- B. They increase the overall coefficient
- C. They have no effect on the coefficient
- D. They double the coefficient

65. Which of the following materials has the highest thermal conductivity?

- A. Air
- B. Copper
- C. Water
- D. Glass

66. Placing a thin radiation shield between two parallel surfaces has what effect?

- A. It increases radiative transfer
- B. It has no effect at all
- C. It reduces the net radiative transfer
- D. It eliminates conduction entirely

Mass Transfer and Separation

67. Molar diffusion flux is expressed in which units?

- A. mol/m³
- B. mol/s
- C. mol/(m²·s)

D. m/s

68. The K-value (y/x) for the more volatile component in a vapour–liquid system is:

A. Greater than 1

B. Less than 1

C. Equal to 0

D. Always exactly 1

69. At the minimum reflux ratio, how many theoretical stages does a distillation column require?

A. An infinite number of stages

B. The minimum number of stages

C. Zero stages

D. Exactly one stage

70. If the liquid flow rate is increased in an absorber, what happens to the absorption factor $A = L/(mV)$?

A. It decreases, reducing recovery

B. It increases, improving recovery

C. It stays constant

D. It becomes negative

71. Random packing is generally preferred over trays in which application?

A. Small-diameter columns needing low pressure drop

B. Very large diameter columns only

C. Heavily fouling, dirty services

D. Columns requiring frequent side draws

72. Crystallisation separates a solid product from solution by:

- A. Raising temperature to increase solubility
- B. Adding a large excess of solvent
- C. Lowering solubility through cooling or evaporation
- D. Applying a strong electric field

73. How does adsorption fundamentally differ from absorption?

- A. The species adheres to a solid surface rather than dissolving into a bulk
- B. The species dissolves uniformly throughout a liquid
- C. The species reacts chemically to form a new compound
- D. The species evaporates into the gas phase

74. Why can an azeotrope not be separated by ordinary distillation?

- A. Its relative volatility is extremely high
- B. The components are completely immiscible
- C. It boils at a very high temperature
- D. Its vapour and liquid compositions are identical at that point

75. In the two-film theory, the overall mass-transfer resistance equals:

- A. The sum of the two film resistances
- B. The larger of the two resistances only
- C. The product of the two resistances

D. Always zero

Solids Handling

76. A 200 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. $1.1 \times 10^{-2} \text{ m/s}$
- B. $4.4 \times 10^{-2} \text{ m/s}$
- C. $2.2 \times 10^{-2} \text{ m/s}$
- D. $8.7 \times 10^{-3} \text{ m/s}$

77. Pneumatic conveying transports bulk solids by means of:

- A. A vibrating screen deck
- B. Gravity rolling alone
- C. Magnetic attraction
- D. A flowing gas stream

78. "Mass flow" in a storage hopper means that:

- A. Only the central core moves while the walls stay static
- B. All the material moves whenever any is discharged
- C. The material remains permanently stagnant
- D. Flow occurs only when vibration is applied

79. What happens to most of the energy supplied to a grinding mill?

- A. It is lost as heat, with little creating new surface

- B. It is converted entirely to new surface area
- C. It is stored as elastic energy in the particles
- D. It is recovered by the downstream classifier

Chemical Reaction Engineering

80. For a zero-order reaction, the reaction rate is:

- A. Proportional to concentration
- B. Independent of concentration
- C. Proportional to the square of concentration
- D. Zero at all times

81. A first-order reaction ($k = 0.2 \text{ min}^{-1}$) 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. 0.63
- C. 0.86
- D. 0.95

82. A CSTR is preferred over a PFR for which type of reaction?

- A. A simple first-order reaction at high conversion
- B. A zero-order reaction in all cases
- C. An endothermic reaction only
- D. An autocatalytic reaction that benefits from back-mixing

83. According to the Arrhenius equation, raising the temperature increases the rate constant because:

- A. The pre-exponential factor A rises sharply
- B. The activation energy itself decreases
- C. The term $\exp(-E_a/RT)$ increases with temperature
- D. The reaction order rises with temperature

84. For the reversible reaction $A \rightleftharpoons B$, the forward rate constant is 4 and the reverse is 2. What is the equilibrium constant?

- A. 8
- B. 0.5
- C. 2
- D. 6

85. The mean residence time of fluid in a flow reactor is given by:

- A. Volume divided by volumetric flow rate
- B. Flow rate divided by volume
- C. Volume multiplied by flow rate
- D. Conversion divided by the rate constant

86. A highly exothermic reaction in a packed-bed reactor poses the principal risk of:

- A. Thermal runaway and localised hot spots
- B. Excessive cooling and freezing
- C. Complete loss of all conversion
- D. Reversal of the reaction direction

Engineering Economics

87. What is the effective annual interest rate for a nominal 12% compounded monthly?

- A. 12.00%
- B. 1.00%
- C. 13.00%
- D. 12.68%

88. What is the present worth of \$30,000 to be received in 3 years at 10% interest ($1.10^3 = 1.331$)?

- A. \$22,539
- B. \$27,273
- C. \$30,000
- D. \$39,930

89. A project is economically justified when its benefit–cost ratio is:

- A. Less than 1
- B. Greater than 1
- C. Equal to 0
- D. Negative

90. A \$50,000 machine is depreciated evenly over 5 years to zero salvage, ignoring interest. What is the annual cost?

- A. \$5,000
- B. \$50,000
- C. \$10,000

D. \$25,000

Process Design

91. The economically optimum reflux ratio in a distillation column is the value that minimises:

- A. Only the number of theoretical stages
- B. Only the steam consumption
- C. The total annual cost of capital plus operating
- D. Only the condenser heat duty

92. Cooling water is preferred over mechanical refrigeration for a duty when:

- A. Very low temperatures are required
- B. The process stream must be frozen
- C. Cryogenic conditions are required
- D. Cooling is needed only to near-ambient temperatures

93. A design (over-design) margin is built into equipment sizing in order to:

- A. Reduce the equipment size
- B. Eliminate the need for control systems
- C. Lower the capital cost directly
- D. Allow for uncertainties and future variations

94. Continuous processing is generally favoured over batch processing for:

- A. Small quantities of many different products

- B. Operations with frequently changing recipes
- C. Large-volume, steady, single-product output
- D. Laboratory-scale research work

95. Installing a spare pump in parallel with the main pump chiefly improves the plant's:

- A. Reliability and availability
- B. Thermal efficiency
- C. Reaction yield
- D. Product purity

96. A HAZOP study is normally carried out using which document as its primary reference?

- A. The P&ID
- B. The block flow diagram
- C. The plot plan
- D. The organisation chart

97. A heat-exchanger network is designed primarily to:

- A. Increase the reaction rate
- B. Raise the product purity
- C. Reduce capital cost alone
- D. Recover heat between streams and reduce utility demand

Process Control

98. Adding integral action to a proportional controller chiefly serves to:

- A. Speed up only the initial response
- B. Eliminate steady-state offset
- C. Add sensitivity to measurement noise
- D. Reduce the controller's gain

99. A closed-loop control system is characterised by its use of:

- A. Feedback of the measured output
- B. No measurement of any kind
- C. Only a fixed timer
- D. Manual adjustment alone

100. A feedback control loop tends to become unstable when:

- A. The controller gain is set very low
- B. The setpoint is held constant
- C. There is no disturbance present
- D. The loop gain is too high near the critical frequency

101. An equal-percentage control valve is characterised by:

- A. Constant flow regardless of stem position
- B. Flow that varies linearly with travel
- C. Maximum flow at the smallest opening

D. An equal percentage change in flow per equal increment of stem movement

Safety, Health, and Environment

102. The minimum oxygen concentration (MOC) is the threshold below which:

- A. Any fuel concentration will ignite
- B. The fuel mixture is always too rich
- C. Combustion cannot be sustained regardless of fuel level
- D. Autoignition always occurs

103. The selection of respiratory protection must be based primarily on:

- A. The worker's personal preference alone
- B. The lowest available purchase cost
- C. Comfort considerations only
- D. The specific airborne contaminant and its concentration

104. A toxic gas that is denser than air, once released, will tend to:

- A. Rise rapidly and disperse
- B. Settle and collect in low-lying areas
- C. Remain fixed at the release height
- D. React with atmospheric nitrogen

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

- A. Welding or other spark-producing work in a hazardous area

- B. Routine office paperwork tasks
- C. Ordering replacement spare parts
- D. Attending a scheduled safety meeting

106. Under the North American classification, a fire involving energised electrical equipment is designated:

- A. Class A
- B. Class B
- C. Class C
- D. Class D

Ethics and Professional Practice

107. An engineer's obligation regarding a client's proprietary information is to keep it:

- A. Published for professional credit
- B. Confidential, including after the engagement ends
- C. Available freely to competitors
- D. Disclosed to the public immediately

108. A professional engineer may apply their seal only to documents that were:

- A. Submitted by any colleague
- B. Produced by any licensed firm
- C. Requested urgently by a client
- D. Prepared by them or under their responsible charge

109. Sustainable engineering practice is defined as the effort to:

- A. Maximise short-term profit alone
- B. Disregard environmental consequences
- C. Meet present needs without compromising future generations
- D. Minimise the documentation effort required

110. The primary purpose of professional engineering licensure is to:

- A. Guarantee higher salaries for licensees
- B. Restrict competition among firms
- C. Protect public health, safety, and welfare
- D. Simplify the hiring process for companies

Practice Exam 7 — Answer Key and Explanations

- 1. C** — A repeated root $r = 2$ from $(r - 2)^2 = 0$ produces the solution $(C_1 + C_2x)e^{(2x)}$, where the extra factor of x supplies the second independent solution. Repeated roots arise in critically damped systems, the boundary between oscillatory and overdamped behaviour.
- 2. A** — The antiderivative of $\cos(x)$ is $\sin(x)$, evaluated from 0 to $\pi/2$ as $\sin(\pi/2) - \sin(0) = 1 - 0 = 1$. Such definite integrals accumulate quantities such as work or transferred mass over an interval.
- 3. C** — A homogeneous system has non-trivial solutions only when its coefficient matrix is singular, that is when $\det A = 0$. A nonzero determinant forces the unique trivial solution, so the vanishing determinant is the condition for a non-zero solution to exist.
- 4. B** — The trapezoidal rule gives $h[(f_0 + f_2)/2 + f_1] = 1[(1 + 5)/2 + 3] = 1[3 + 3] = 6$. This numerical estimate replaces the curve with straight segments, the simplest practical integration scheme.
- 5. B** — Euler's identity gives $e^{(i\pi)} = \cos(\pi) + i \cdot \sin(\pi) = -1 + 0 = -1$. This relation links exponential and trigonometric functions and is central to analysing oscillatory and complex-frequency responses.
- 6. A** — Differentiating $f = x^2y^3$ with respect to x gives $2xy^3$, and then with respect to y gives $6xy^2$. Mixed partials appear in exact-differential criteria and in thermodynamic Maxwell relations.
- 7. C** — By the total-probability rule, the overall defect rate is $0.6 \times 0.02 + 0.4 \times 0.05 = 0.012 + 0.020 = 0.032$, or 3.2%. Weighting each source by its production share gives the combined quality level for the whole output.

- 8. D** — The standard error of the mean is $\sigma/\sqrt{n} = 10/\sqrt{25} = 10/5 = 2$. Larger samples shrink the standard error, tightening confidence intervals on the estimated mean.
- 9. A** — The number of combinations is $C(6,2) = 6!/(2!4!) = 15$. Combinations count selections where order does not matter, distinct from the 30 ordered permutations.
- 10. D** — The expected sum of two fair dice is the sum of each die's expectation, $3.5 + 3.5 = 7$. Expectation adds linearly, which is why 7 is also the most probable single total.
- 11. B** — The parallel system fails only if both components fail, with probability $0.1 \times 0.1 = 0.01$, so it works with probability $1 - 0.01 = 0.99$. Redundancy sharply improves reliability by requiring simultaneous failures.
- 12. C** — Power is force times velocity, $50 \times 4 = 200$ W. This relation gives the rate of doing work and sizes the drive needed to move equipment at a target speed.
- 13. D** — Stored energy in a capacitor is $\frac{1}{2}CV^2 = \frac{1}{2} \times 2 \times 10^2 = 100$ J. The square dependence on voltage means modest voltage increases store disproportionately more energy.
- 14. B** — Maximum friction force is $\mu N = 0.3 \times 200 = 60$ N. This product sets the resistance that must be overcome to initiate sliding between surfaces.
- 15. D** — Work at constant pressure is $P\Delta V = 100,000 \times 0.02 = 2000$ J. This expansion work is the energy a gas delivers as it pushes back its surroundings.
- 16. A** — Young's modulus quantifies stiffness, the resistance to elastic deformation under stress. A high modulus means small deflection under load, distinct from hardness or toughness.
- 17. D** — Fatigue is progressive cracking under repeated cyclic loading, occurring even at stresses below the ultimate strength. Designing below the endurance limit guards against this common cause of unexpected failure.
- 18. B** — Creep is slow, time-dependent deformation under sustained load at elevated temperature. It limits the safe service life of components such as boiler tubes and turbine blades.
- 19. A** — A thermoplastic can be repeatedly melted and reshaped because its chains are not cross-linked, unlike a thermoset that sets permanently. This reprocessability makes thermoplastics recyclable and easy to mould.
- 20. A** — Carbon dissolved in iron strengthens and hardens steel by impeding dislocation motion within the lattice. The carbon content is the primary lever for tuning a steel's mechanical properties.
- 21. C** — At 25 °C, $\text{pH} + \text{pOH} = 14$, so $\text{pOH} = 14 - 4 = 10$. This relation links the acidic and basic measures of a solution through the ion product of water.

- 22. B** — Dividing each mass percent by atomic mass gives moles of 3.33 C : 6.7 H : 3.33 O, a 1 : 2 : 1 ratio, so the empirical formula is CH₂O. The empirical formula expresses the simplest whole-number atom ratio.
- 23. D** — One mole of an ideal gas occupies 22.4 L at standard temperature and pressure. This molar volume converts directly between moles and gas volume in stoichiometric work.
- 24. B** — Neutralisation of HCl by NaOH is one-to-one, so equal molarity requires equal volume, 50 mL. Equating moles of acid and base locates the equivalence point of a titration.
- 25. A** — The reaction goes from 4 mol of gas to 2 mol, so raising pressure shifts equilibrium toward the products, the side with fewer gas moles. This Le Chatelier response is exploited by running ammonia synthesis at high pressure.
- 26. B** — DNA encodes genetic information with a four-letter alphabet of nucleotide bases. The sequence of these bases specifies the order of amino acids during protein synthesis.
- 27. C** — The species that loses electrons is oxidised and, by donating those electrons, acts as the reducing agent. Tracking which species is oxidised is essential to balancing redox equations.
- 28. B** — A concentration of 5 mg in 1 kg (10⁶ mg) of water is 5 parts per million. The ppm unit is standard for trace contaminants in water and air.
- 29. D** — Reynolds number is $\rho v D / \mu = (800 \times 1.5 \times 0.1) / 0.002 = 60,000$. This places the flow firmly in the turbulent regime, dictating the friction correlation used.
- 30. B** — Continuity gives $v_2 = v_1 A_1 / A_2 = 4 \times 0.08 / 0.16 = 2$ m/s. Doubling the area halves the velocity, conserving the volumetric flow.
- 31. A** — Dynamic pressure is $\frac{1}{2} \rho v^2 = \frac{1}{2} \times 1000 \times 10^2 = 50,000$ Pa = 50 kPa. This kinetic contribution converts to static pressure when the flow is brought to rest, as in a Pitot tube.
- 32. D** — In fully turbulent flow at high Reynolds number, the friction factor depends mainly on the relative pipe roughness, becoming nearly independent of Reynolds number. This is why pipe condition dominates losses in rough, fast flows.
- 33. C** — Shaft power is $\rho g Q H / \eta = (1000 \times 9.81 \times 0.02 \times 15) / 0.75 = 2943 / 0.75 = 3.92$ kW. Dividing the ideal power by efficiency gives the actual input the motor must provide.
- 34. C** — Absolute pressure equals gauge plus atmospheric, 150 + 101 = 251 kPa. Converting to absolute is essential for gas-law and thermodynamic calculations, which require absolute values.
- 35. D** — A venturi meter relates flow rate to the pressure drop measured across its throat, applying Bernoulli's equation. The constriction accelerates the fluid, and the resulting pressure difference indicates the flow.

- 36. A** — A floating body is in equilibrium when the upward buoyant force equals its own weight, by Archimedes' principle. The body sinks to the depth at which it displaces exactly its weight of fluid.
- 37. B** — For pipe segments in series, the total head loss is the sum of the individual losses, since the same flow passes through each in turn. Adding losses segment by segment sizes the pump for the whole line.
- 38. B** — Carnot efficiency is $1 - T_c/T_h = 1 - 300/500 = 0.40$, or 40%. This temperature-only ceiling cannot be exceeded by any engine between the two reservoirs.
- 39. A** — Internal energy change at constant volume is $nC_v\Delta T = 3 \times 20 \times 25 = 1500$ J. The constant-volume heat capacity applies because no expansion work is done.
- 40. C** — Work output is $\eta \times Q_{in} = 0.30 \times 1000 = 300$ J. Thermal efficiency is the fraction of supplied heat converted to useful work, the rest being rejected.
- 41. D** — Every irreversible process increases the total entropy of the system plus surroundings, making the change positive. This statement of the second law sets the direction of all spontaneous change.
- 42. B** — The dew point is the temperature at which a cooling vapour mixture first begins to condense, forming the first drop of liquid. It bounds the condensation behaviour relevant to drying and gas processing.
- 43. D** — Fugacity is an effective pressure that corrects the ideal-gas relations for non-ideal behaviour, so that real equilibria can be computed with familiar formulas. It reduces to pressure as the gas approaches ideality.
- 44. A** — Below its inversion temperature a gas has a positive Joule–Thomson coefficient, so it cools when throttled at constant enthalpy. This cooling is the working principle of many refrigeration and liquefaction processes.
- 45. C** — In a Rankine cycle the working fluid is pumped as a liquid before entering the boiler, which keeps the pump work small. Compressing a liquid requires far less work than compressing a vapour, raising cycle efficiency.
- 46. D** — For an ideal solution the enthalpy of mixing is zero, because the interactions between unlike molecules match those between like molecules. Real mixtures with stronger or weaker cross-interactions show a nonzero heat of mixing.
- 47. C** — Recycling unreacted feed allows it to react on subsequent passes, so the overall conversion is higher than the single-pass value. This is why recycle loops are used to achieve high utilisation of expensive reactants.
- 48. B** — The dry solid is 50 kg; removing 40 kg of water leaves 10 kg of water in a 60 kg product, giving a moisture content of $10/60 = 16.7\%$. Tracking the constant dry mass is the reliable path through drying balances.

- 49. A** — Burning 12 kg (1 kmol) of carbon produces 1 kmol of CO₂, which has a mass of 44 kg. Combustion stoichiometry fixes the carbon dioxide output for emissions accounting.
- 50. B** — The combined salt is $10 + 30 = 40$ kg in 200 kg of mixture, giving 20%. A component balance on the mixer yields the blended composition.
- 51. B** — Selectivity is desired product over by-product, $50/25 = 2$. A higher selectivity reduces waste and downstream separation, often the key economic driver.
- 52. D** — A purge stream bleeds off a portion of the recycle to prevent inert or unreactive species from accumulating in the loop. Without it, inerts would build up until they choked the process.
- 53. A** — In an adiabatic reactor the heat released by an exothermic reaction cannot escape, so the temperature rises. This self-heating must be managed to avoid runaway in strongly exothermic systems.
- 54. B** — A double-effect evaporator uses the vapour generated in the first effect as the heating medium for the second, reusing the latent heat. This cascading of vapour markedly reduces steam consumption.
- 55. C** — Percentage excess is $(\text{supplied} - \text{required})/\text{required} = (5 - 4)/4 = 25\%$. The surplus oxygen drives combustion to completion while passing through unreacted.
- 56. D** — A component that passes through a unit unchanged serves as a tie component, linking inlet and outlet flows. Tie-component analysis simplifies balances when direct measurement is incomplete.
- 57. B** — Per 100 g, moles are $50/20 = 2.5$ of A and $50/80 = 0.625$ of B, so the mole fraction of A is $2.5/3.125 = 0.80$. Converting mass to mole basis weights the lighter component more heavily.
- 58. D** — Fourier's law gives $Q = kA\Delta T/L = (15 \times 2 \times 50)/0.05 = 30,000 \text{ W} = 30 \text{ kW}$. The thin, conductive wall passes a large heat rate for the given temperature difference.
- 59. C** — Rearranging $Q = hA\Delta T$ gives $h = Q/(A\Delta T) = 2000/(4 \times 25) = 20 \text{ W/m}^2\cdot\text{K}$. The convective coefficient measures how effectively fluid motion removes heat from the surface.
- 60. C** — A black body is an ideal emitter and absorber with an emissivity of 1, the theoretical maximum. Real surfaces have emissivities below one, scaled relative to this ideal.
- 61. A** — When both terminal temperature differences are equal, the log-mean reduces to that common value, 20 °C. The LMTD only departs from the arithmetic mean when the two end differences differ.
- 62. D** — Conductive heat loss is inversely proportional to thickness, so doubling the insulation roughly halves the loss. This inverse relation guides the economic choice of insulation thickness.
- 63. B** — Boiling involves latent-heat transfer and vigorous bubble motion, giving coefficients far higher than single-phase natural convection. This is why boiling and condensing services achieve compact, high-duty exchangers.

- 64. A** — Fouling adds a thermal resistance on the heat-transfer surface, reducing the overall coefficient U . Designers include a fouling allowance and schedule cleaning to maintain performance.
- 65. B** — Copper has a very high thermal conductivity, far exceeding water, glass, and air. This is why copper is the standard material for heat-exchanger tubes and heat sinks.
- 66. C** — A radiation shield inserted between two surfaces adds intermediate radiating surfaces that reduce the net radiative heat transfer. Multiple shields, as in superinsulation, cut radiation dramatically.
- 67. C** — Molar flux is the moles transferred per unit area per unit time, with units of $\text{mol}/(\text{m}^2 \cdot \text{s})$. These units follow directly from Fick's law and parallel the heat flux in W/m^2 .
- 68. A** — The K -value, y/x , exceeds one for the more volatile component because it concentrates in the vapour. This ratio drives the vapour enrichment that makes distillation possible.
- 69. A** — At the minimum reflux ratio a column would need an infinite number of stages, since the operating and equilibrium lines pinch together. Real columns operate above the minimum to keep the stage count finite.
- 70. B** — Increasing the liquid rate raises the absorption factor $L/(mV)$, improving solute recovery into the liquid. A higher absorption factor is a primary means of boosting absorber performance.
- 71. A** — Random packing is favoured for small-diameter columns and where a low pressure drop is needed, as in vacuum service. Trays become more economical and serviceable at larger diameters.
- 72. C** — Crystallisation forms a solid product by lowering its solubility, typically through cooling or solvent evaporation, until the solution becomes supersaturated. Controlling supersaturation governs crystal size and purity.
- 73. A** — In adsorption a species adheres to a solid surface, whereas in absorption it dissolves into the bulk of a liquid. This surface-versus-bulk distinction explains why adsorbents are chosen for their surface area.
- 74. D** — At an azeotrope the vapour and liquid have identical compositions, so no further enrichment occurs and ordinary distillation cannot separate the components. Breaking an azeotrope requires methods such as pressure swing or an added entrainer.
- 75. A** — In the two-film theory the overall resistance to mass transfer is the sum of the two film resistances in series. The film with the lower coefficient contributes the larger resistance and controls the rate.
- 76. C** — Stokes' law gives $v = gd^2\Delta\rho/(18\mu) = (9.81 \times (2 \times 10^{-4})^2 \times 1000)/(18 \times 10^{-3}) = 2.2 \times 10^{-2} \text{ m/s}$. The square dependence on diameter makes settling velocity highly size-sensitive.
- 77. D** — Pneumatic conveying moves bulk solids by entraining them in a flowing gas stream through ducts. It suits fine, free-flowing powders and offers flexible, enclosed routing.

78. B — In mass flow, all the stored material moves whenever any is discharged, giving first-in-first-out behaviour with no stagnant zones. This flow pattern prevents caking and segregation in hoppers.

79. A — Most of the energy supplied to a grinding mill is dissipated as heat, with only a small fraction creating new particle surface. This inherent inefficiency makes comminution one of the most energy-intensive operations.

80. B — A zero-order reaction proceeds at a rate independent of reactant concentration, limited instead by a factor such as catalyst surface or light intensity. Its concentration falls linearly with time until reactant is exhausted.

81. C — For a first-order PFR, conversion is $X = 1 - e^{(-k\tau)} = 1 - e^{(-0.2 \times 10)} = 1 - e^{(-2)} = 1 - 0.135 = 0.86$. The plug-flow form reaches high conversion efficiently for first-order kinetics.

82. D — A CSTR is preferred for an autocatalytic reaction, where its back-mixing maintains the high product concentration that accelerates the rate. For ordinary positive-order kinetics, a PFR is more efficient.

83. C — Raising temperature increases the rate constant because the Arrhenius factor $\exp(-E_a/RT)$ grows as T rises, allowing more molecules to surmount the energy barrier. The activation energy itself is unchanged.

84. C — At equilibrium the forward and reverse rates balance, so $K = k_{\text{forward}}/k_{\text{reverse}} = 4/2 = 2$. This links measurable kinetic constants to the equilibrium position.

85. A — Mean residence time is reactor volume divided by volumetric flow rate, the average time fluid spends in the vessel. It connects reactor size to throughput and conversion.

86. A — Strongly exothermic reactions in a packed bed risk thermal runaway and localised hot spots if heat is generated faster than it can be removed. Adequate cooling and temperature monitoring are essential to safe operation.

87. D — The effective rate is $(1 + 0.12/12)^{12} - 1 = (1.01)^{12} - 1 = 0.1268$, or 12.68%. Monthly compounding makes the effective rate exceed the nominal rate.

88. A — Present worth is $F/(1 + i)^n = 30,000/1.10^3 = 30,000/1.331 = \$22,539$. Discounting reflects that a future sum is worth less than the same amount today.

89. B — A project is economically justified when its benefit–cost ratio exceeds one, meaning discounted benefits outweigh discounted costs. A ratio below one signals a net economic loss.

90. C — Even depreciation over 5 years to zero salvage is $50,000/5 = \$10,000$ per year. This straight-line allocation spreads the cost uniformly across the service life.

- 91. C** — The economically optimum reflux ratio minimises the total annual cost, balancing the capital cost of more stages against the operating cost of more reflux. Operating exactly at minimum or total reflux is never economic.
- 92. D** — Cooling water is preferred when the duty only needs cooling to near-ambient temperatures, since it avoids the expense of refrigeration. Below ambient, mechanical refrigeration becomes necessary.
- 93. D** — A design margin is added to allow for uncertainties in data, fouling, and future operating changes. This over-design provides a buffer so the unit still meets duty under off-design conditions.
- 94. C** — Continuous processing suits large-volume, steady production of a single product, where its efficiency and consistent quality outweigh its inflexibility. Batch processing is better for small or varied production.
- 95. A** — A spare pump in parallel improves reliability and availability, allowing operation to continue if one pump fails. This redundancy protects continuous processes against single-equipment outages.
- 96. A** — A HAZOP study uses the P&ID as its primary reference, since that diagram shows every line, valve, and instrument needed to examine deviations. The detail of the P&ID supports the systematic node-by-node review.
- 97. D** — A heat-exchanger network is designed to recover heat between hot and cold process streams, cutting the demand for external heating and cooling utilities. This integration is a principal route to energy savings.
- 98. B** — Integral action eliminates steady-state offset by continuing to adjust the output until the error reaches zero. This is why PI and PID controllers, unlike pure proportional control, reach the setpoint exactly.
- 99. A** — A closed-loop system feeds back the measured output and compares it with the setpoint to drive corrective action. This feedback is what distinguishes closed-loop from open-loop control.
- 100. D** — A loop tends toward instability when its open-loop gain is too high at the frequency where the phase lag reaches the critical value, causing growing oscillations. Gain and phase margins quantify how far a loop stays from this condition.
- 101. D** — An equal-percentage valve gives an equal percentage change in flow for each equal increment of stem travel, providing fine control at low flow. This characteristic suits loops with widely varying process gain.
- 102. C** — The minimum oxygen concentration is the level below which combustion cannot be sustained regardless of how much fuel is present. Inerting a vessel below the MOC is a reliable fire-prevention measure.

103. D — Respiratory protection must be matched to the specific airborne contaminant and its concentration, since different hazards require different filters or supplied air. Selecting the wrong device leaves the worker unprotected.

104. B — A toxic gas denser than air settles and collects in low-lying areas such as pits and trenches. Recognising this dispersion behaviour guides monitor placement and confined-space precautions.

105. A — A hot-work permit is required before welding or other spark-producing work in a hazardous area, to confirm the space is free of flammable atmosphere. This control prevents ignition during maintenance.

106. C — Under the North American system, a fire involving energised electrical equipment is a Class C fire, requiring a non-conductive extinguishing agent. Using water or a conductive agent would risk electrocution.

107. B — An engineer must keep a client's proprietary information confidential, an obligation that continues even after the engagement ends. Protecting such information preserves trust and meets ethical and often contractual duties.

108. D — A professional engineer may seal only documents prepared by them or under their responsible charge, since the seal certifies personal responsibility for the work. Sealing others' unsupervised work misrepresents accountability.

109. C — Sustainable engineering seeks to meet present needs without compromising the ability of future generations to meet theirs. This principle integrates environmental, economic, and social considerations into design.

110. C — The primary purpose of engineering licensure is to protect the health, safety, and welfare of the public by ensuring practitioners are competent. Licensure exists for public protection, not to benefit the engineer's earnings or limit competition.