

PRACTICE EXAM 12: FE CHEMICAL SIMULATION (110 QUESTIONS)

Mathematics

1. What is the general solution of the differential equation $y'' + 9y = 0$?

A. $y = C_1e^{(3x)} + C_2e^{(-3x)}$

B. $y = (C_1 + C_2x)e^{(3x)}$

C. $y = C_1\cos(3x) + C_2\sin(3x)$

D. $y = C_1e^{(9x)}$

2. Evaluate the definite integral of \sqrt{x} from $x = 1$ to $x = 4$.

A. 7

B. 3.5

C. 9

D. 4.67

3. The inverse of a 2×2 matrix exists only when its determinant is:

A. Nonzero

B. Zero

C. Negative

D. Equal to one

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

- A. x
- B. $1/x$
- C. $\ln(x)$
- D. e^x

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

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

6. The dot product of two perpendicular vectors is:

- A. 1
- B. 0
- C. Their combined magnitude
- D. -1

Probability and Statistics

7. A fair coin is flipped twice. What is the probability of obtaining two heads?

- A. 0.5
- B. 0.25
- C. 0.75
- D. 1.0

8. What is the median of the data set 4, 8, 15, 16, 23, and 42?

- A. 15
- B. 16
- C. 15.5
- D. 18

9. In how many ordered ways can 3 items be selected from a set of 4 distinct items?

- A. 12
- B. 4
- C. 64
- D. 24

10. Multiplying every value in a data set by 2 changes the variance by a factor of:

- A. 2
- B. 1
- C. 4
- D. 8

11. A fair six-sided die is rolled and the player wins the face value in dollars. What is the expected winning?

- A. \$3
- B. \$3.5
- C. \$6
- D. \$21

Engineering Sciences

12. A 100 N force moves an object 10 m at an angle of 60° to the displacement. How much work is done ($\cos 60^\circ = 0.5$)?

- A. 1000 J
- B. 866 J
- C. 500 J
- D. 0 J

13. Two $4\ \Omega$ resistors are connected in parallel. What is the equivalent resistance?

- A. $2\ \Omega$
- B. $8\ \Omega$
- C. $4\ \Omega$
- D. $16\ \Omega$

14. An object accelerates uniformly from rest to 20 m/s in 5 seconds. What is its acceleration?

- A. $100\ \text{m/s}^2$
- B. $0.25\ \text{m/s}^2$
- C. $4\ \text{m/s}^2$
- D. $20\ \text{m/s}^2$

15. A current of 2 A flows through a $6\ \Omega$ resistor. What is the voltage across it?

- A. 3 V
- B. 12 V
- C. 8 V

D. 0.33 V

Materials Science

16. The maximum stress a material can withstand before failure is its:

- A. Yield strength
- B. Proportional limit
- C. Elastic modulus
- D. Ultimate tensile strength

17. Cold working a metal generally:

- A. Decreases strength and increases ductility
- B. Has no effect on its properties
- C. Changes only its colour
- D. Increases strength but decreases ductility

18. The two most densely packed metallic crystal structures are face-centred cubic and:

- A. Body-centred cubic
- B. Hexagonal close-packed
- C. Simple cubic
- D. Amorphous

19. Pitting corrosion is characterised by:

- A. Uniform thinning across the surface

- B. Cracking under sustained stress
- C. Complete dissolution of the metal
- D. Localised holes in an otherwise intact surface

20. Vulcanisation of rubber works by introducing:

- A. Carbon fibres for stiffness
- B. Plasticisers for softness
- C. Sulphur cross-links to improve elasticity and strength
- D. Metal particles for conductivity

Chemistry and Biology

21. What is the pH of a 0.01 M solution of a strong monoprotic acid?

- A. 2
- B. 12
- C. 0.01
- D. 7

22. What is the molar mass of sulphuric acid, H_2SO_4 ?

- A. 80 g/mol
- B. 64 g/mol
- C. 98 g/mol
- D. 49 g/mol

23. What volume does one mole of an ideal gas occupy at 273 K and 101.3 kPa ($R = 8.314 \text{ J/mol}\cdot\text{K}$)?

- A. 1 L
- B. 8.3 L
- C. 273 L
- D. 22.4 L

24. Removing a product from a system at equilibrium shifts the equilibrium toward:

- A. Forming more product
- B. Forming more reactant
- C. No net change
- D. Stopping the reaction

25. For $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$ with excess hydrogen, how many moles of ammonia form from 4 mol of nitrogen?

- A. 4 mol
- B. 12 mol
- C. 8 mol
- D. 2 mol

26. In most of its compounds, the oxidation state of oxygen is:

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

27. The minimum energy that colliding molecules must possess for a reaction to occur is the:

- A. Heat of reaction
- B. Bond energy
- C. Internal energy
- D. Activation energy

28. Which molecule stores hereditary information within cells?

- A. DNA
- B. ATP
- C. Glucose
- D. Cellulose

Fluid Mechanics

29. A fluid (density 1000 kg/m^3 , viscosity $1 \times 10^{-3} \text{ Pa}\cdot\text{s}$) flows at 0.5 m/s through a 0.04 m pipe. What is the Reynolds number?

- A. 20000
- B. 2000
- C. 200
- D. 2

30. Flow at 4 m/s in a 0.06 m^2 duct enters a 0.02 m^2 section. What is the velocity in the smaller section?

- A. 1.33 m/s
- B. 4 m/s
- C. 12 m/s
- D. 6 m/s

31. Bernoulli's equation expresses the conservation of:

- A. Mass only
- B. Momentum only
- C. Mechanical energy along a streamline
- D. Temperature

32. What is the hydrostatic pressure at a depth of 4 m in water (density 1000 kg/m^3)?

- A. 4 kPa
- B. 39.2 kPa
- C. 392 kPa
- D. 3.92 kPa

33. For laminar pipe flow at a Reynolds number of 800, what is the Darcy friction factor?

- A. 0.08
- B. 64
- C. 0.8
- D. 0.008

34. A pump delivers $0.06 \text{ m}^3/\text{s}$ of water against a head of 8 m. What is the ideal hydraulic power?

- A. 4.71 kW
- B. 0.47 kW
- C. 47 kW
- D. 471 W

35. A flow of $0.8 \text{ m}^3/\text{s}$ passes through a duct of cross-sectional area 0.4 m^2 . What is the velocity?

- A. 0.5 m/s
- B. 0.32 m/s
- C. 8 m/s
- D. 2 m/s

36. Using the Darcy equation with $f = 0.03$, $L = 80 \text{ m}$, $D = 0.08 \text{ m}$, and $v = 2 \text{ m/s}$, what is the head loss?

- A. 3.06 m
- B. 12.2 m
- C. 6.12 m
- D. 1.22 m

37. The drag coefficient of a body is primarily a function of its:

- A. Mass alone
- B. Shape and Reynolds number
- C. Colour
- D. Temperature alone

Thermodynamics

38. A Carnot engine operates between 900 K and 450 K . What is its maximum efficiency?

- A. 25%
- B. 75%
- C. 50%

D. 40%

39. Five moles of an ideal gas ($C_v = 20 \text{ J/mol}\cdot\text{K}$) are heated by 10 K at constant volume. What is the change in internal energy?

A. 1000 J

B. 500 J

C. 2000 J

D. 100 J

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

A. 100 J

B. 300 J

C. 200 J

D. 500 J

41. Steam enters an adiabatic turbine at 3300 kJ/kg and leaves at 2800 kJ/kg, flowing at 2 kg/s. What is the shaft power?

A. 500 kW

B. 1000 kW

C. 1500 kW

D. 2000 kW

42. A Carnot heat pump operates between 270 K and 300 K. What is its heating coefficient of performance, $T_h/(T_h - T_c)$?

A. 9

- B. 11
- C. 10
- D. 0.1

43. An equimolar liquid mixture of A (pure vapour pressure 160 kPa) and B (80 kPa) follows Raoult's law. What is the bubble-point pressure?

- A. 80 kPa
- B. 120 kPa
- C. 160 kPa
- D. 240 kPa

44. What is the value of the compressibility factor for an ideal gas?

- A. 0
- B. 1
- C. Infinity
- D. Its molar mass

45. For an isentropic process, the entropy change is:

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

46. A reaction with a negative enthalpy change and a positive entropy change is:

- A. Never spontaneous

- B. Spontaneous only at high temperature
- C. Spontaneous only at low temperature
- D. Spontaneous at all temperatures

Material and Energy Balances

47. An 800 kg/h feed is separated into a 500 kg/h product stream and a second stream. What is the flow rate of the second stream?
- A. 1300 kg/h
 - B. 300 kg/h
 - C. 500 kg/h
 - D. 800 kg/h
48. An evaporator concentrates 1200 kg/h of a 15% solids feed to a 45% solids product. How much water is evaporated?
- A. 400 kg/h
 - B. 180 kg/h
 - C. 720 kg/h
 - D. 800 kg/h
49. Complete combustion of ethylene follows $\text{C}_2\text{H}_4 + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 2\text{H}_2\text{O}$. How many moles of oxygen are needed for 2 mol of ethylene?
- A. 6 mol
 - B. 3 mol
 - C. 4 mol
 - D. 12 mol

50. A 200 kg stream of 15% salt is mixed with a 200 kg stream of 45% salt. What is the salt content of the mixture?

- A. 15%
- B. 30%
- C. 60%
- D. 45%

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

- A. 25%
- B. 75%
- C. 100%
- D. 200 mol

52. A process recycles 500 mol/h and receives a fresh feed of 500 mol/h. What is the recycle ratio?

- A. 1
- B. 2
- C. 1000
- D. 0.5

53. How much heat is required to raise 40 kg of water by 15 °C, with a specific heat of 4.18 kJ/kg·K?

- A. 627 kJ
- B. 1254 kJ
- C. 4180 kJ
- D. 2508 kJ

54. A solid has a moisture content of 60% on a dry basis. What is the equivalent moisture content on a wet basis?

- A. 60%
- B. 40%
- C. 150%
- D. 37.5%

55. In the reaction $3A \rightarrow 2B$, 9 mol of A reacts completely. How many moles of B are formed?

- A. 9 mol
- B. 3 mol
- C. 6 mol
- D. 18 mol

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

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

57. A material balance problem is solvable when the number of independent equations equals:

- A. The number of unknowns
- B. Zero
- C. Twice the number of unknowns
- D. The number of streams only

Heat Transfer

58. A 0.1 m thick wall ($k = 4 \text{ W/m}\cdot\text{K}$, area 2 m^2) has a $45 \text{ }^\circ\text{C}$ temperature difference across it. What is the conductive heat rate?

- A. 360 W
- B. 720 W
- C. 1800 W
- D. 3600 W

59. A 3 m^2 surface transfers 1500 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. $50 \text{ W/m}^2\cdot\text{K}$

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

- A. $9\times$
- B. $81\times$
- C. $27\times$
- D. $3\times$

61. In a counter-current exchanger, the hot stream cools from $110 \text{ }^\circ\text{C}$ to $70 \text{ }^\circ\text{C}$ while the cold stream warms from $20 \text{ }^\circ\text{C}$ to $60 \text{ }^\circ\text{C}$. What is the log-mean temperature difference?

- A. $50 \text{ }^\circ\text{C}$

- B. 45 °C
- C. 0 °C
- D. 100 °C

62. Two wall layers have thermal resistances of 0.4 K/W and 0.6 K/W in series. What is the total resistance?

- A. 0.24 K/W
- B. 0.5 K/W
- C. 1.0 K/W
- D. 0.2 K/W

63. Two convective films of 300 and 600 W/m²·K act in series with negligible wall resistance. What is the overall coefficient U?

- A. 900 W/m²·K
- B. 450 W/m²·K
- C. 100 W/m²·K
- D. 200 W/m²·K

64. An exchanger has $U = 200 \text{ W/m}^2 \cdot \text{K}$, area 6 m², and a log-mean temperature difference of 25 °C. What is the heat duty?

- A. 6 kW
- B. 12 kW
- C. 30 kW
- D. 60 kW

65. Heat conduction always flows from:

- A. High temperature to low temperature
- B. Low temperature to high temperature
- C. High pressure to low pressure
- D. The direction of fluid flow

66. A surface with a low emissivity is:

- A. A good radiator and poor reflector
- B. A perfect black body
- C. A poor radiator and good reflector
- D. A perfect absorber

Mass Transfer and Separation

67. A species diffuses through a 1 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. $3 \times 10^{-8} \text{ mol/m}^2 \cdot \text{s}$
- B. $1.5 \times 10^{-5} \text{ mol/m}^2 \cdot \text{s}$
- C. $3 \times 10^{-5} \text{ mol/m}^2 \cdot \text{s}$
- D. $3 \times 10^{-3} \text{ mol/m}^2 \cdot \text{s}$

68. For a relative volatility of 5, what vapour composition is in equilibrium with a liquid of mole fraction 0.2?

- A. 0.20
- B. 0.40
- C. 0.80
- D. 0.56

69. The two limiting operating conditions of a distillation column are total reflux and:

- A. Minimum reflux
- B. Zero stages
- C. Maximum pressure
- D. Critical reflux

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 99% of a solute, so $C_{in}/C_{out} = 100$. What is the number of transfer units, $NTU = \ln(C_{in}/C_{out})$?

- A. 0.99
- B. 4.6
- C. 100
- D. 2.0

72. Equilibrium solubility data for gas absorption are commonly represented by:

- A. Henry's law
- B. Fourier's law
- C. Ohm's law
- D. Hooke's law

73. The falling-rate period of drying is controlled by:

- A. The external air velocity alone
- B. The wet-bulb temperature alone
- C. Radiation from the heater
- D. Internal moisture diffusion to the surface

74. Microfiltration removes particles larger than approximately:

- A. 1 nanometre
- B. 0.1 micrometre
- C. 1 metre
- D. Individual dissolved ions

75. The Schmidt number in mass transfer is the analogue of which heat-transfer group?

- A. The Prandtl number
- B. The Nusselt number
- C. The Reynolds number
- D. The Froude number

Solids Handling

76. A 200 μm particle ($\Delta\rho = 1800 \text{ kg/m}^3$) settles in a fluid of viscosity $2 \times 10^{-3} \text{ Pa}\cdot\text{s}$. What is its Stokes' law terminal velocity?

- A. $9.8 \times 10^{-3} \text{ m/s}$
- B. $3.9 \times 10^{-2} \text{ m/s}$
- C. $5.9 \times 10^{-3} \text{ m/s}$

D. 1.96×10^{-2} m/s

77. A particle with a sphericity less than 1 is:

- A. Perfectly spherical
- B. Non-spherical
- C. Of zero volume
- D. In the liquid state

78. A centrifuge improves separation chiefly by:

- A. Heating the mixture
- B. Reducing the density difference
- C. Adding a filter aid
- D. Applying a force many times that of gravity

79. A notable drawback of pneumatic conveying is:

- A. An inability to enclose the material
- B. A consistently very low throughput
- C. An unsuitability for any powders
- D. High energy use and particle attrition

Chemical Reaction Engineering

80. A first-order reaction ($k = 0.1 \text{ min}^{-1}$) starts at 3 mol/L. What is the concentration after 10 minutes, using $C = C_0 e^{-kt}$?

- A. 1.10 mol/L
- B. 0.30 mol/L

- C. 1.5 mol/L
- D. 0.37 mol/L

81. A first-order reaction ($k = 0.5 \text{ min}^{-1}$) runs in a PFR with a space time of 4 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 ($k = 0.3 \text{ min}^{-1}$) reaches 90% conversion in a CSTR. What space time is required?

- A. 30 min
- B. 15 min
- C. 3 min
- D. 9 min

83. That a reaction rate roughly doubles for a 10°C temperature rise reflects:

- A. A linear dependence on temperature
- B. Zero-order behaviour
- C. Independence from activation energy
- D. The exponential temperature dependence of the Arrhenius equation

84. For the reversible reaction $A \rightleftharpoons B$, the forward rate constant is 12 and the reverse is 4. What is the equilibrium constant?

- A. 16

- B. 8
- C. 0.33
- D. 3

85. A reaction yields 120 mol of desired product and 40 mol of by-product. What is the selectivity?

- A. 3.0
- B. 0.33
- C. 120
- D. 40

86. An adiabatic reactor running an endothermic reaction shows, along its length, a:

- A. Rising temperature
- B. Falling temperature
- C. Constant temperature
- D. Oscillating temperature

Engineering Economics

87. What is the future worth of \$7,000 invested for 5 years at 6% interest ($1.06^5 = 1.3382$)?

- A. \$7,420
- B. \$8,400
- C. \$10,500
- D. \$9,367

88. What is the present worth of \$25,000 to be received in 5 years at 10% interest ($1.10^5 = 1.6105$)?

- A. \$15,523
- B. \$22,727
- C. \$25,000
- D. \$40,263

89. A \$90,000 asset with a \$10,000 salvage value is depreciated straight-line over 5 years. What is the annual depreciation?

- A. \$18,000
- B. \$16,000
- C. \$20,000
- D. \$80,000

90. What is the capitalised cost of a perpetual annual expense of \$8,000 at an interest rate of 8%, using $P = A/i$?

- A. \$100,000
- B. \$64,000
- C. \$640
- D. \$8,640

Process Design

91. Which engineering diagram shows control loops and instrumentation in full detail?

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

92. The typical exponent used in the six-tenths rule for scaling equipment cost with capacity is about:

- A. 1.0
- B. 0.6
- C. 2.0
- D. 0.1

93. Equipment that cost \$120,000 at a cost index of 800 is re-estimated at a current index of 1000. What is the updated cost?

- A. \$150,000
- B. \$96,000
- C. \$120,000
- D. \$200,000

94. In a heat-exchanger network, the minimum approach temperature is set at the:

- A. Condenser
- B. Pinch point
- C. Reboiler
- D. Feed inlet

95. For a slow liquid-phase reaction requiring a long residence time, a suitable reactor choice is:

- A. A short plug-flow tube
- B. A flash drum
- C. A batch reactor or large CSTR
- D. A cyclone

96. For handling corrosive chlorine gas, a suitable material of construction is:

- A. Ordinary carbon steel
- B. A nickel alloy or other resistant metal
- C. Untreated aluminium
- D. Plain copper

97. The purpose of a flare system in a process plant is to:

- A. Generate process steam
- B. Cool the main reactor
- C. Store excess product gas
- D. Safely burn off relieved or waste gases

Process Control

98. Which controller mode anticipates future error from its present rate of change?

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

99. A differential-pressure cell installed across an orifice plate is used to infer:

- A. Temperature
- B. Flow rate
- C. Composition

D. pH

100. The desired value that a controller continuously tries to maintain is called the:

A. Offset

B. Gain

C. Set point

D. Dead band

101. A feedback loop with insufficient gain margin tends to:

A. Respond instantly

B. Eliminate steady-state offset

C. Remain perfectly steady

D. Oscillate or become unstable

Safety, Health, and Environment

102. Inerting a vessel with nitrogen prevents fire by reducing the:

A. Fuel concentration to zero

B. Oxygen concentration below the combustion-supporting level

C. Temperature below the flash point

D. Pressure to atmospheric

103. Fault tree analysis proceeds:

A. From a top event downward to its contributing causes

B. From causes upward to possible outcomes

- C. By applying guide words to deviations
- D. By ranking project costs

104. A key limitation of personal protective equipment as a control measure is that it:

- A. Eliminates the hazard entirely
- B. Is always the cheapest option
- C. Protects only the wearer and depends on correct use
- D. Requires no training to use

105. A carcinogen is a substance that:

- A. Can cause cancer
- B. Is always flammable
- C. Neutralises acids
- D. Is biologically inert

106. The Clean Air Act principally regulates:

- A. Hazardous solid waste
- B. Discharges to water
- C. Workplace noise
- D. Emissions to the atmosphere

Ethics and Professional Practice

107. Reporting a serious, unresolved public danger to outside authorities after internal channels have failed is:

- A. A breach of loyalty
- B. Ethically justified whistleblowing
- C. Always prohibited conduct
- D. Automatic grounds for licence loss

108. Presenting estimated results as though they were measured data is:

- A. Acceptable in early design
- B. Required to save time
- C. A form of dishonesty to be avoided
- D. Standard professional practice

109. To maintain technical competence over a career, engineers should:

- A. Rely only on past experience
- B. Avoid unfamiliar new methods
- C. Pursue continuing professional development
- D. Delegate all unfamiliar work

110. A trade secret remains legally protected for as long as:

- A. It is kept confidential
- B. A fixed 20-year term runs
- C. It is publicly disclosed
- D. It is registered with a patent office

Practice Exam 12 – Answer Key and Explanations

- 1. C** — The characteristic equation $r^2 + 9 = 0$ gives imaginary roots $r = \pm 3i$, producing the oscillatory solution $C_1\cos(3x) + C_2\sin(3x)$. Imaginary roots always yield sine–cosine solutions, the form of undamped vibration.
- 2. D** — The antiderivative of \sqrt{x} is $(2/3)x^{3/2}$, evaluated from 1 to 4 as $(2/3)(8 - 1) = 14/3 \approx 4.67$. Definite integration accumulates the area under the curve.
- 3. A** — A 2×2 matrix is invertible only when its determinant is nonzero, since the inverse divides by that determinant. A zero determinant marks a singular, non-invertible matrix.
- 4. B** — The derivative of $\ln(x)$ is $1/x$. This standard result is central to integrating reciprocals and solving growth-rate problems.
- 5. C** — The limit of $\sin(x)/x$ as x approaches 0 is 1, a foundational result. It underlies small-angle approximations and the differentiation of trigonometric functions.
- 6. B** — The dot product of perpendicular vectors is zero, because the cosine of the 90° angle between them is zero. A zero dot product is the test for orthogonality.
- 7. B** — Each flip is independent with probability 0.5, so two heads occur with probability $0.5 \times 0.5 = 0.25$. Multiplying probabilities applies to independent successive events.
- 8. C** — With six ordered values, the median is the average of the third and fourth, $(15 + 16)/2 = 15.5$. The median is the midpoint of the ordered data.
- 9. D** — The ordered selection count is $P(4,3) = 4 \times 3 \times 2 = 24$. Permutations count arrangements where order matters.
- 10. C** — Multiplying every value by 2 scales the variance by the square of the factor, $2^2 = 4$. Variance carries squared units, so it grows with the square of any scaling.
- 11. B** — The expected value of a fair die is the average of its faces, $(1 + 2 + 3 + 4 + 5 + 6)/6 = 3.5$. Expectation gives the long-run average outcome.
- 12. C** — Work is $Fd \cdot \cos \theta = 100 \times 10 \times \cos 60^\circ = 100 \times 10 \times 0.5 = 500$ J. Only the component of force along the displacement does work.
- 13. A** — Two equal resistors in parallel give half the value, $4/2 = 2 \Omega$. The parallel result is always less than either individual resistor.
- 14. C** — Acceleration is the change in velocity over time, $20/5 = 4$ m/s². Uniform acceleration relates velocity change to elapsed time linearly.
- 15. B** — Ohm's law gives $V = IR = 2 \times 6 = 12$ V. Voltage is proportional to both current and resistance.

- 16. D** — The ultimate tensile strength is the maximum stress a material can sustain before failure. It is distinct from the yield strength, where permanent deformation begins.
- 17. D** — Cold working hardens and strengthens a metal through dislocation build-up but reduces its ductility. This work-hardening trade-off is exploited and managed in metal forming.
- 18. B** — The two close-packed structures are face-centred cubic and hexagonal close-packed, both achieving the maximum atomic packing fraction. Body-centred cubic is slightly less densely packed.
- 19. D** — Pitting corrosion forms localised holes in an otherwise sound surface, where a small anodic area corrodes rapidly. These deep, narrow pits can cause failure with little overall metal loss.
- 20. C** — Vulcanisation introduces sulphur cross-links between rubber chains, improving its elasticity, strength, and temperature resistance. The cross-links convert soft raw rubber into a durable elastomer.
- 21. A** — For a 0.01 M strong monoprotic acid, $[H^+] = 0.01$ and $pH = -\log(0.01) = 2$. Complete dissociation makes the hydrogen-ion concentration equal to the acid concentration.
- 22. C** — Summing atomic masses, $2H (2) + S (32) + 4O (64) = 98$ g/mol. Molar mass converts between mass and moles in stoichiometry.
- 23. D** — One mole of ideal gas occupies $V = RT/P = (8.314 \times 273)/101,300 = 0.0224$ m³ = 22.4 L at standard conditions. This molar volume is a standard reference point.
- 24. A** — Removing a product disturbs the equilibrium, and by Le Chatelier's principle the system shifts to form more product. This shift is exploited to drive reactions toward completion.
- 25. C** — With excess hydrogen, the one-to-two stoichiometry gives 2 mol of ammonia per mole of nitrogen, so 4 mol of nitrogen yields 8 mol. Nitrogen is the limiting reactant and sets the product amount.
- 26. A** — Oxygen carries an oxidation state of -2 in most of its compounds. This consistent value is a cornerstone for assigning oxidation states and balancing redox reactions.
- 27. D** — The activation energy is the minimum energy colliding molecules must possess to react. Only molecules exceeding this barrier form products, which is why temperature so strongly affects rate.
- 28. A** — DNA stores the hereditary information of cells in its sequence of nucleotide bases. This genetic code directs the synthesis of proteins and the inheritance of traits.
- 29. A** — Reynolds number is $\rho vD/\mu = (1000 \times 0.5 \times 0.04)/0.001 = 20,000$. This turbulent value sets the appropriate friction correlation.
- 30. C** — Continuity gives $v_2 = v_1A_1/A_2 = 4 \times (0.06/0.02) = 12$ m/s. The threefold area reduction triples the velocity.

- 31. C** — Bernoulli's equation expresses the conservation of mechanical energy — pressure, kinetic, and potential — along a streamline. It applies to steady, incompressible, frictionless flow.
- 32. B** — Hydrostatic pressure is $\rho gh = 1000 \times 9.81 \times 4 = 39,240 \text{ Pa} \approx 39.2 \text{ kPa}$. Pressure rises linearly with depth.
- 33. A** — For laminar flow, the friction factor is $64/\text{Re} = 64/800 = 0.08$. The inverse dependence on Reynolds number gives higher friction at lower flow.
- 34. A** — Ideal hydraulic power is $\rho gQH = 1000 \times 9.81 \times 0.06 \times 8 = 4708.8 \text{ W} \approx 4.71 \text{ kW}$. Dividing by efficiency would give the shaft power.
- 35. D** — Velocity is flow over area, $0.8/0.4 = 2 \text{ m/s}$. This follows directly from the continuity equation.
- 36. C** — The Darcy equation gives $h_f = f(L/D)(v^2/2g) = 0.03 \times (80/0.08) \times (4/19.62) = 6.12 \text{ m}$. Friction head loss scales with the square of velocity.
- 37. B** — The drag coefficient depends chiefly on the body's shape and the Reynolds number of the flow. It captures how the geometry and flow regime together set the resistance.
- 38. C** — Carnot efficiency is $1 - T_c/T_h = 1 - 450/900 = 0.50$, or 50%. The temperature ratio alone fixes this ceiling.
- 39. A** — Internal energy change at constant volume is $nC_v\Delta T = 5 \times 20 \times 10 = 1000 \text{ J}$. The constant-volume heat capacity applies because no work is done.
- 40. D** — The first law gives $Q = \Delta U + W = 300 + 200 = 500 \text{ J}$. Heat supplied both raises internal energy and does work.
- 41. B** — Adiabatic turbine power is $\dot{m}(h_1 - h_2) = 2 \times (3300 - 2800) = 1000 \text{ kW}$. The enthalpy drop converts directly into shaft work.
- 42. C** — The heating coefficient of performance is $T_h/(T_h - T_c) = 300/30 = 10$. The small temperature lift gives a high COP.
- 43. B** — Raoult's law gives the bubble pressure as $0.5 \times 160 + 0.5 \times 80 = 120 \text{ kPa}$. The total pressure is the mole-fraction-weighted sum of the pure vapour pressures.
- 44. B** — An ideal gas has a compressibility factor of exactly 1, since $PV = nRT$ holds without correction. Departures from one measure the degree of non-ideal behaviour.
- 45. D** — An isentropic process has, by definition, zero entropy change, being reversible and adiabatic. It is the ideal benchmark for compressors and turbines.
- 46. D** — With ΔH negative and ΔS positive, $\Delta G = \Delta H - T\Delta S$ is negative at every temperature, so the reaction is spontaneous at all temperatures. Both the enthalpy and entropy terms favour the products.

- 47. B** — A steady-state mass balance gives the second stream as $800 - 500 = 300$ kg/h. Conservation of mass closes the separation.
- 48. D** — A solids balance gives $0.15 \times 1200 = 0.45 \times L$, so the product is $L = 400$ kg/h, and water evaporated = $1200 - 400 = 800$ kg/h. The non-volatile solids fix the product rate.
- 49. A** — At 3 mol of oxygen per mole of ethylene, 2 mol of ethylene needs $2 \times 3 = 6$ mol. Combustion stoichiometry sets the oxygen demand.
- 50. B** — The combined salt is $0.15 \times 200 + 0.45 \times 200 = 30 + 90 = 120$ kg in 400 kg, giving 30%. A component balance yields the blended composition.
- 51. B** — Conversion is $(800 - 200)/800 = 75\%$. This fraction measures how completely the feed is consumed.
- 52. A** — The recycle ratio is recycle over fresh feed, $500/500 = 1$. Equal recycle and fresh feed give a ratio of one.
- 53. D** — Sensible heat is $mC_p\Delta T = 40 \times 4.18 \times 15 = 2508$ kJ. This relation sizes the heating duty for a temperature change.
- 54. D** — Converting 60% dry basis gives wet basis = $60/(100 + 60) = 37.5\%$. The wet basis is always the smaller figure because its denominator includes the water.
- 55. C** — The stoichiometry consumes three moles of A per two of B, so 9 mol of A yields 6 mol of B. Reaction stoichiometry converts reactant consumed into product formed.
- 56. C** — Percentage excess is $(15 - 12)/12 = 25\%$. The surplus oxygen ensures complete combustion.
- 57. A** — A material balance is solvable when the number of independent equations equals the number of unknowns, giving zero degrees of freedom. Fewer equations leave the system underspecified.
- 58. D** — Fourier's law gives $Q = kA\Delta T/L = (4 \times 2 \times 45)/0.1 = 3600$ W. Conductive heat rate scales with conductivity, area, and driving temperature.
- 59. C** — Rearranging $Q = hA\Delta T$ gives $h = 1500/(3 \times 25) = 20$ W/m²·K. The coefficient measures how effectively the fluid removes heat.
- 60. B** — Emissive power scales with the fourth power of absolute temperature, so tripling T raises it by $3^4 = 81$ times. This steep dependence makes radiation dominant at high temperatures.
- 61. A** — Both terminal differences are $110 - 60 = 50$ °C and $70 - 20 = 50$ °C, so the log-mean equals that common value, 50 °C. When the end differences match, the LMTD reduces to that single value.
- 62. C** — Series thermal resistances add directly, $0.4 + 0.6 = 1.0$ K/W. The thermal-circuit analogy makes composite-wall analysis straightforward.

- 63. D** — With negligible wall resistance, $1/U = 1/300 + 1/600 = 0.005$, so $U = 200 \text{ W/m}^2\cdot\text{K}$. The overall coefficient is smaller than either film coefficient.
- 64. C** — Exchanger duty is $UA\Delta T = 200 \times 6 \times 25 = 30,000 \text{ W} = 30 \text{ kW}$. This product of coefficient, area, and driving force sizes the exchanger.
- 65. A** — Heat conduction always flows from a region of higher temperature to one of lower temperature, in line with the second law. The temperature difference is the driving force.
- 66. C** — A low-emissivity surface is a poor radiator and, equivalently, a good reflector of thermal radiation. Such surfaces, like polished metals, are used to limit radiant heat exchange.
- 67. C** — Fick's law gives flux $= D \cdot \Delta C / \delta = (3 \times 10^{-9} \times 10) / (1 \times 10^{-3}) = 3 \times 10^{-5} \text{ mol/m}^2\cdot\text{s}$. Flux rises with diffusivity and concentration difference and falls with film thickness.
- 68. D** — Using $y = \alpha x / [1 + (\alpha - 1)x] = (5 \times 0.2) / (1 + 4 \times 0.2) = 1.0 / 1.8 = 0.56$. The vapour is enriched in the volatile component relative to the liquid.
- 69. A** — A distillation column's two operating limits are total reflux, giving the minimum stages, and minimum reflux, requiring infinite stages. Real columns operate between these bounds.
- 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. B** — The number of transfer units is $\ln(C_{\text{in}}/C_{\text{out}}) = \ln(100) \approx 4.6$. The high NTU reflects the demanding 99% removal.
- 72. A** — Equilibrium solubility of a gas in a liquid is commonly described by Henry's law, relating dissolved concentration to partial pressure. It underpins the design of absorbers.
- 73. D** — In the falling-rate period, drying is limited by the internal diffusion of moisture from within the solid to its surface. This slower internal transport controls the second stage of drying.
- 74. B** — Microfiltration removes particles larger than roughly 0.1 micrometre, such as bacteria and fine suspended solids. Finer separations down to ions require ultrafiltration or reverse osmosis.
- 75. A** — The Schmidt number is the mass-transfer analogue of the Prandtl number, each being a ratio of diffusivities. This analogy lets heat-transfer correlations be adapted for mass transfer.
- 76. D** — Stokes' law gives $v = gd^2\Delta\rho / (18\mu) = (9.81 \times (2 \times 10^{-4})^2 \times 1800) / (18 \times 2 \times 10^{-3}) = 1.96 \times 10^{-2} \text{ m/s}$. The square dependence on diameter makes settling highly size-sensitive.
- 77. B** — A sphericity below one indicates a non-spherical particle, since a perfect sphere has a sphericity of exactly one. The shape factor affects drag, packing, and flow behaviour.

- 78. D** — A centrifuge applies a force many times that of gravity, greatly accelerating the settling of particles or the separation of phases. This intensified field separates mixtures that would settle far too slowly under gravity.
- 79. D** — A drawback of pneumatic conveying is its high energy consumption and the particle attrition caused by high-velocity impacts. These costs must be weighed against its flexible, enclosed routing.
- 80. A** — First-order decay gives $C = C_0 e^{-kt} = 3 \times e^{-(0.1 \times 10)} = 3 \times e^{-1} = 3 \times 0.368 = 1.10$ mol/L. The concentration falls exponentially at a rate fixed by k .
- 81. B** — For a first-order PFR, conversion is $X = 1 - e^{-k\tau} = 1 - e^{-(0.5 \times 4)} = 1 - e^{-2} = 0.86$. The plug-flow reactor reaches high conversion efficiently.
- 82. A** — For a first-order CSTR, $\tau = X/[k(1 - X)] = 0.9/(0.3 \times 0.1) = 30$ min. High conversion in a CSTR demands a long residence time because it operates at the low exit concentration.
- 83. D** — The roughly doubling of rate per 10 °C reflects the exponential temperature dependence of the Arrhenius factor $\exp(-E_a/RT)$. Small temperature rises sharply increase the fraction of molecules able to react.
- 84. D** — At equilibrium the forward and reverse rates balance, so $K = k_{\text{forward}}/k_{\text{reverse}} = 12/4 = 3$. This links the kinetic constants to the equilibrium position.
- 85. A** — Selectivity is desired product over by-product, $120/40 = 3$. A high selectivity reduces waste and downstream separation.
- 86. B** — In an adiabatic endothermic reactor, the reaction absorbs heat with none supplied, so the temperature falls along the reactor length. This cooling can quench the reaction unless heat is added.
- 87. D** — Future worth is $P(1 + i)^n = 7000 \times 1.06^5 = 7000 \times 1.3382 = \$9,367$. Compounding grows the sum forward at the stated rate.
- 88. A** — Present worth is $F/(1 + i)^n = 25,000/1.10^5 = 25,000/1.6105 = \$15,523$. Discounting reflects that a future sum is worth less today.
- 89. B** — Straight-line depreciation is $(90,000 - 10,000)/5 = \$16,000$ per year. This even allocation spreads the depreciable basis across the service life.
- 90. A** — Capitalised cost of a perpetual annual amount is $A/i = 8000/0.08 = \$100,000$. This perpetuity formula values an endless stream of equal payments as a single sum.
- 91. D** — The P&ID shows the control loops and instrumentation in full detail, serving as the master document for the control system. Its detail exceeds that of the block flow and process flow diagrams.
- 92. B** — The six-tenths rule scales equipment cost with capacity using an exponent of about 0.6. This value captures the economy of scale typical of process equipment.

- 93. A** — Updating with the cost index gives $120,000 \times (1000/800) = \$150,000$. The index ratio corrects the historical cost for inflation.
- 94. B** — In a heat-exchanger network, the minimum approach temperature occurs at the pinch point, the location that limits further heat integration. The pinch sets the targets for minimum utility use.
- 95. C** — A slow liquid-phase reaction needing a long residence time suits a batch reactor or a large CSTR, which readily provide extended contact time. A short plug-flow tube would not give sufficient residence.
- 96. B** — Corrosive chlorine gas requires a resistant material such as a suitable nickel alloy, since carbon steel and common metals corrode rapidly. Material selection here is critical to prevent a hazardous leak.
- 97. D** — A flare system safely burns off relieved or waste gases, converting hazardous releases into less harmful combustion products. It is a key safety feature for handling overpressure and venting.
- 98. C** — Derivative control action responds to the rate of change of the error, anticipating where the error is heading. It improves response to fast disturbances but amplifies measurement noise.
- 99. B** — A differential-pressure cell across an orifice plate infers flow rate from the measured pressure drop. This is one of the most common industrial flow-measurement methods.
- 100. C** — The set point is the desired value that a controller continuously works to maintain. The controller acts on the difference between the set point and the measured variable.
- 101. D** — A loop with insufficient gain margin lies too close to instability and tends to oscillate or grow unstable. Adequate gain and phase margins keep the loop safely damped.
- 102. B** — Nitrogen inerting reduces the oxygen concentration below the level that supports combustion, preventing ignition of flammable vapours. This protects vessels during filling, emptying, and maintenance.
- 103. A** — Fault tree analysis works deductively from a defined top event down through the combinations of causes that could produce it. This top-down logic identifies the failure paths leading to an incident.
- 104. C** — Personal protective equipment protects only the individual wearing it and depends on correct, consistent use. This reliance on human behaviour is why PPE is the least reliable control tier.
- 105. A** — A carcinogen is a substance capable of causing cancer through prolonged or significant exposure. Identifying carcinogens guides exposure limits and handling precautions.
- 106. D** — The Clean Air Act principally regulates emissions to the atmosphere, setting limits on air pollutants from industrial sources. Compliance shapes a plant's stack and vent control requirements.
- 107. B** — Reporting a serious, unresolved public danger to outside authorities after internal channels have failed is ethically justified whistleblowing. The paramount duty to public safety can override the usual obligation of confidentiality to an employer.

108. C — Presenting estimates as measured data is a form of dishonesty that misrepresents the basis of the work. Engineers must be transparent about the source and reliability of the figures they report.

109. C — Maintaining competence requires ongoing continuing professional development to keep current with evolving methods and technology. This sustained learning protects the quality and safety of an engineer's work.

110. A — A trade secret stays legally protected only as long as it is kept confidential, with no fixed expiry term. Once disclosed publicly, the protection is lost, unlike a patent's defined-term grant.