PRACTICE EXAM 13: FE CHEMICAL SIMULATION (110 QUESTIONS)

Mathematics

1. Solve the separable equation $dy/dx = xy$. Which form describes the general solution?

A. $y = Cx^2$

B. $y = Ce^x$

C. $y = Ce^{(x^2/2)}$

D. $y = C\cdot\ln(x)$

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

A. 0

B. 2

C. 1

D. −2

3. What is the determinant of the 3 × 3 identity matrix?

A. 0

B. 3

C. 9

D. 1

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

A. $e^{(-x)}$

B. e^x

C. $xe^{(-x)}$

D. $-e^{(-x)}$

5. Evaluate the limit of $(x^2 - 4)/(x - 2)$ as x approaches 2.

A. 0

B. 2

C. 4

D. Infinity

6. What is the magnitude of any unit vector?

A. 0

B. 1

C. The sum of its components

D. Variable

Probability and Statistics

7. A single card is drawn from a standard 52-card deck. What is the probability that it is a heart?

A. 0.50

B. 0.077

C. 0.25

D. 0.75

8. What is the arithmetic mean of the data set 12, 14, 16, 18, and 20?

A. 14

B. 18

C. 16

D. 80

9. In how many ways can 2 items be chosen from 10 distinct items, where order does not matter?

A. 90

B. 45

C. 20

D. 100

10. The standard deviation of a data set is expressed in:

A. The same units as the original data

B. The units of the variance

C. Dimensionless form

D. The squared units of the data

11. A binomial process has 50 trials with a success probability of 0.2. What is the expected number of successes?

A. 50

B. 0.2

C. 8

D. 10

Engineering Sciences

12. A constant force of 200 N moves an object at a steady 3 m/s in the direction of the force. What power is delivered?

A. 600 W

B. 67 W

C. 203 W

D. 197 W

13. Two resistors of 8 Ω and 12 Ω are connected in series. What is the total resistance?

A. 4.8 Ω

B. 20 Ω

C. 96 Ω

D. 10 Ω

14. A net force accelerates an 8 kg mass at 2.5 m/s^2. What is the magnitude of the force?

A. 3.2 N

B. 20 N

C. 10.5 N

D. 0.31 N

15. A 4 kg object moves at 10 m/s. What is its kinetic energy?

A. 40 J

B. 20 J

C. 200 J

D. 400 J

Materials Science

16. A stiffer material is characterised by a:

A. Lower elastic modulus

B. Zero modulus

C. Higher Young's modulus

D. Higher density alone

17. The endurance limit of a material is the stress below which:

A. It can endure effectively infinite load cycles

B. Immediate fracture occurs

C. Creep dominates

D. Corrosion ceases

18. The liquidus line on a phase diagram marks the temperature above which:

A. The alloy is fully liquid

B. The alloy is fully solid

C. Only ferrite exists

D. Corrosion begins

19. Painting a steel surface protects it from corrosion by:

A. Acting as a sacrificial anode

B. Acting as a barrier to moisture and oxygen

C. Raising the steel's melting point

D. Supplying a cathodic current

20. The matrix phase in a composite material principally serves to:

A. Carry all the applied load directly

B. Bind the reinforcement and transfer load between fibres

C. Conduct electricity

D. Lower the melting point

Chemistry and Biology

21. An aqueous solution has a hydrogen ion concentration of 1×10^{-6} mol/L. What is its pH?

A. 8

B. 1×10^{-6}

C. 6

D. 7

22. What is the molar mass of methane, CH_4?

A. 12 g/mol

B. 28 g/mol

C. 32 g/mol

D. 16 g/mol

23. A fixed quantity of gas at 2 atm has its volume halved at constant temperature. What is the new pressure?

A. 1 atm

B. 2 atm

C. 4 atm

D. 0.5 atm

24. A defining feature of a catalyst is that it accelerates a reaction without:

A. Being consumed

B. Lowering the activation energy

C. Providing a new reaction path

D. Affecting the rate

25. For $2Al + 3Cl_2 \rightarrow 2AlCl_3$ with excess chlorine, how many moles of $AlCl_3$ form from 4 mol of aluminium?

A. 2 mol

B. 6 mol

C. 4 mol

D. 8 mol

26. What is the molarity of a solution containing 0.5 mol of solute in 250 mL of solution?

A. 0.125 M

B. 0.5 M

C. 2 M

D. 1.25 M

27. An ionic bond is formed by:

A. Sharing electron pairs between atoms

B. A sea of delocalised electrons

C. Dipole attraction alone

D. The transfer of electrons between atoms

28. Cellular respiration produces usable energy chiefly in the form of:

A. ATP

B. DNA

C. Glucose

D. Protein

Fluid Mechanics

29. A fluid (density 1000 kg/m^3, viscosity 0.01 Pa·s) flows at 1.2 m/s through a 0.05 m pipe. What is the Reynolds number?

A. 600

B. 6000

C. 60000

D. 1200

30. Flow at 5 m/s in a 0.08 m^2 duct enters a 0.02 m^2 section. What is the velocity in the smaller section?

A. 1.25 m/s

B. 5 m/s

C. 10 m/s

D. 20 m/s

31. At the throat of a horizontal venturi, where the velocity rises, the static pressure:

A. Rises

B. Stays constant

C. Doubles

D. Falls

32. What is the hydrostatic pressure at a depth of 6 m in water (density 1000 kg/m^3)?

A. 6 kPa

B. 600 kPa

C. 58.9 kPa

D. 5.89 kPa

33. For laminar pipe flow at a Reynolds number of 160, what is the Darcy friction factor?

A. 0.4

B. 64

C. 4.0

D. 0.04

34. A pump delivers 0.05 m^3/s of water against a head of 20 m. What is the ideal hydraulic power?

A. 0.98 kW

B. 98 kW

C. 9.81 kW

D. 981 W

35. A fluid flows at 4 m/s through a duct of cross-sectional area 0.15 m^2. What is the volumetric flow rate?

A. 0.0375 m^3/s

B. 6 m^3/s

C. 0.6 m^3/s

D. 60 m^3/s

36. A high Reynolds number indicates that:

A. Viscous forces dominate

B. The flow is laminar

C. Gravity dominates

D. Inertial forces dominate over viscous forces

37. A manometer measures pressure by balancing it against:

A. A calibrated spring

B. A strain gauge

C. An electric current

D. A column of liquid

Thermodynamics

38. A Carnot engine operates between 800 K and 400 K. What is its maximum efficiency?

A. 25%

B. 75%

C. 50%

D. 40%

39. Two moles of an ideal gas ($C_v = 25$ J/mol·K) are heated by 20 K at constant volume. What is the change in internal energy?

A. 1000 J

B. 500 J

C. 2000 J

D. 250 J

40. A closed system absorbs 600 J of heat while doing 250 J of work. What is the change in internal energy?

A. 850 J

B. 350 J

C. −350 J

D. 600 J

41. Steam enters an adiabatic turbine at 3000 kJ/kg and leaves at 2600 kJ/kg, flowing at 6 kg/s. What is the shaft power?

A. 400 kW

B. 1200 kW

C. 2400 kW

D. 1800 kW

42. A refrigerator removes 600 W from the cold space while consuming 240 W of work. What is its coefficient of performance?

A. 4

B. 3.5

C. 0.4

D. 2.5

43. An equimolar liquid mixture of A (pure vapour pressure 100 kPa) and B (60 kPa) follows Raoult's law. What is the bubble-point pressure?

A. 60 kPa

B. 80 kPa

C. 100 kPa

D. 160 kPa

44. Within an isolated system, the entropy:

A. Always decreases

B. Is always constant

C. Is always zero

D. Never decreases

45. A thermodynamic process carried out at constant pressure is described as:

A. Adiabatic

B. Isothermal

C. Isobaric

D. Isochoric

46. An endothermic reaction has a heat of reaction that is:

A. Positive

B. Negative

C. Zero

D. Always equal to its entropy change

Material and Energy Balances

47. Two streams of 350 kg/h and 450 kg/h are combined in a mixer. What is the product flow rate at steady state?

A. 800 kg/h

B. 100 kg/h

C. 350 kg/h

D. 450 kg/h

48. An evaporator concentrates 600 kg/h of a 20% solids feed to a 50% solids product. What is the product flow rate?

A. 360 kg/h

B. 240 kg/h

C. 120 kg/h

D. 480 kg/h

49. Complete combustion of carbon follows $C + O_2 \rightarrow CO_2$. How many moles of oxygen are needed for 3 mol of carbon?

A. 6 mol

B. 3 mol

C. 1.5 mol

D. 9 mol

50. A 100 kg stream of 25% salt is mixed with a 100 kg stream of 55% salt. What is the salt content of the mixture?

A. 25%

B. 55%

C. 40%

D. 80%

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

A. 25%

B. 75%

C. 100%

D. 150 mol

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

A. 0.25

B. 1

C. 1000

D. 4

53. How much heat is required to raise 25 kg of water by 20 °C, with a specific heat of 4.18 kJ/kg·K?

A. 522 kJ

B. 1045 kJ

C. 4180 kJ

D. 2090 kJ

54. A solid has a moisture content of 25% on a dry basis. What is the equivalent moisture content on a wet basis?

A. 20%

B. 25%

C. 75%

D. 33%

55. In the reaction 2A → 3B, 4 mol of A reacts completely. How many moles of B are formed?

A. 4 mol

B. 6 mol

C. 12 mol

D. 8 mol

56. A burner needs 10 mol of oxygen stoichiometrically but is supplied with 12.5 mol. What is the percentage excess oxygen?

A. 20%

B. 25%

C. 80%

D. 125%

57. In a reactor material balance, the maximum amount of product that can form is fixed by the:

A. Limiting reactant

B. Excess reactant

C. Inert gas present

D. Recycle stream

Heat Transfer

58. A 0.2 m thick wall ($k = 0.5$ W/m·K, area 4 m^2) has a 30 °C temperature difference across it. What is the conductive heat rate?

A. 300 W

B. 600 W

C. 1200 W

D. 150 W

59. A 3 m^2 surface transfers heat by convection with $h = 30$ W/m^2·K and a temperature difference of 20 °C. What is the heat rate?

A. 900 W

B. 1800 W

C. 600 W

D. 3600 W

60. The emissive power of a black body is proportional to its absolute temperature raised to the power of:

A. 1

B. 2

C. 4

D. 3

61. In a counter-current exchanger, the hot stream cools from 90 °C to 60 °C while the cold stream warms from 25 °C to 45 °C. What is the log-mean temperature difference?

A. 40 °C

B. 45 °C

C. 39.8 °C

D. 35 °C

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

A. 1.0 K/W

B. 0.25 K/W

C. 0.5 K/W

D. 0.1 K/W

63. Two convective films, each 250 $W/m^2 \cdot K$, act in series with negligible wall resistance. What is the overall coefficient U?

A. 500 $W/m^2 \cdot K$

B. 125 $W/m^2 \cdot K$

C. 250 $W/m^2 \cdot K$

D. 62.5 $W/m^2 \cdot K$

64. An exchanger has U = 300 $W/m^2 \cdot K$, area 10 m^2, and a log-mean temperature difference of 20 °C. What is the heat duty?

A. 6 kW

B. 12 kW

C. 30 kW

D. 60 kW

65. Heat transferred by the bulk motion of a fluid is termed:

A. Convection

B. Conduction

C. Radiation

D. Diffusion

66. Wrapping a hot pipe in insulation reduces heat loss by:

A. Increasing the surface area

B. Raising the fluid temperature

C. Increasing the conductive thermal resistance

D. Emitting more radiation

Mass Transfer and Separation

67. A species diffuses through a 1 mm film with $D = 2.5 \times 10^{-9}$ m²/s and a concentration difference of 8 mol/m³. What is the molar flux?

A. 2×10^{-5} mol/m²·s

B. 2×10^{-8} mol/m²·s

C. 4×10^{-5} mol/m²·s

D. 2×10^{-3} mol/m²·s

68. For the more volatile component of a mixture, the equilibrium ratio y/x is:

A. Greater than 1

B. Less than 1

C. Exactly 1

D. Zero

69. At total reflux, a distillation column requires the:

A. Maximum number of stages

B. Minimum number of stages

C. An infinite number of stages

D. Zero stages

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

A. 0.50

B. 0.67

C. 0.33

D. 0.25

71. A packed column has an HTU of 0.5 m and requires 8 transfer units. What is the packed height?

A. 0.5 m

B. 8 m

C. 16 m

D. 4.0 m

72. The solubility of a gas in a liquid generally decreases as:

A. The pressure increases

B. The concentration falls

C. The molar mass falls

D. The temperature increases

73. An azeotrope can sometimes be separated by:

A. Simply adding more stages

B. Raising the reflux to infinity

C. Changing the operating pressure

D. Cooling below freezing

74. The overall mass-transfer coefficient combines the gas-film and liquid-film resistances:

A. In series

B. In parallel

C. By multiplication

D. By subtraction

75. The constant-rate period of drying ends at the:

A. Equilibrium moisture content

B. Zero moisture content

C. Critical moisture content

D. Saturation point

Solids Handling

76. A 150 μm particle ($\Delta\rho = 1000$ kg/m³) settles in a fluid of viscosity 1×10^{-3} Pa·s. What is its Stokes' law terminal velocity?

A. 6.1×10^{-3} m/s

B. 1.23×10^{-2} m/s

C. 2.5×10^{-2} m/s

D. 4.9×10^{-3} m/s

77. In a screening operation, the oversize material is the fraction that:

A. Passes through the screen

B. Is retained on the screen

C. Dissolves in water

D. Evaporates

78. At the point of minimum fluidisation, the bed pressure drop equals the:

A. Weight of the bed per unit area

B. Atmospheric pressure

C. Zero value

D. Velocity head alone

79. Grinding a powder primarily increases its:

A. Density

B. Moisture content

C. Melting point

D. Specific surface area

Chemical Reaction Engineering

80. A first-order reaction ($k = 0.5\ min^{-1}$) starts at 2 mol/L. What is the concentration after 2 minutes, using $C = C_0e^{(-kt)}$?

A. 1.0 mol/L

B. 0.74 mol/L

C. 0.37 mol/L

D. 0.5 mol/L

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

A. 0.50

B. 0.63

C. 0.78

D. 0.86

82. A first-order reaction ($k = 0.3\ min^{-1}$) reaches 60% conversion in a CSTR. What space time is required?

A. 2 min

B. 3 min

C. 5 min

D. 10 min

83. A zero-order reaction has $k = 1.5$ mol/L·min and an initial concentration of 6 mol/L. What is its half-life, $t_{½} = C_0/(2k)$?

A. 4 min

B. 2 min

C. 3 min

D. 1 min

84. For the reversible reaction A ⇌ B, the forward rate constant is 15 and the reverse is 3. What is the equilibrium constant?

A. 18

B. 12

C. 0.2

D. 5

85. A catalyst changes the time taken to reach equilibrium but does not change the:

A. Equilibrium conversion

B. Reaction rate

C. Activation energy

D. Reaction pathway

86. A rate constant carrying units of mol/(L·s) corresponds to a reaction of which order?

A. First order

B. Zero order

C. Second order

D. Third order

Engineering Economics

87. What is the future worth of $10,000 invested for 6 years at 7% interest ($1.07^6 = 1.5007$)?

A. \$11,400

B. \$13,000

C. \$14,200

D. \$15,007

88. A vessel costs \$200,000 at a capacity of 5 m^3. Using the six-tenths rule, estimate the cost of a 25 m^3 vessel ($5^{0.6} = 2.627$).

A. \$1,000,000

B. \$200,000

C. \$525,000

D. \$720,000

89. A project requires \$1,200,000 of capital and returns \$300,000 per year. What is the simple payback period?

A. 2 yr

B. 3 yr

C. 6 yr

D. 4 yr

90. A project returns \$2,500 at the end of each year for 12 years at 8% interest (P/A factor 7.5361). What is its present worth?

A. \$30,000

B. \$2,500

C. \$25,000

D. \$18,840

Process Design

91. Which diagram conveys the overall process concept in its simplest form?

A. The P&ID

B. The block flow diagram

C. The process flow diagram

D. The plot plan

92. The optimum operating temperature for a reversible exothermic reactor balances:

A. Reaction rate against equilibrium conversion

B. Capital cost against catalyst cost alone

C. Pressure against viscosity

D. Flow against level

93. Equipment that cost $150,000 at a cost index of 750 is re-estimated at a current index of 1000. What is the updated cost?

A. $112,500

B. $150,000

C. $200,000

D. $250,000

94. For a duty requiring a very large heat-transfer area within a compact footprint, a suitable choice is:

A. A plate-and-frame exchanger

B. A single jacketed vessel

C. An open trough

D. A bare pipe

95. For pumping a clean liquid at high flow and low head, the preferred pump type is:

A. A piston metering pump

B. A gear pump

C. A diaphragm pump

D. A centrifugal pump

96. For a vessel storing concentrated nitric acid, a suitable material of construction is:

A. Mild steel

B. Copper

C. Painted plain aluminium

D. Stainless steel

97. A rupture disc is preferred over a relief valve when:

A. A fast-acting, non-reclosing device is needed

B. Frequent venting and reseating is expected

C. Precise set-pressure control is required

D. The fluid is perfectly clean and slow-changing

Process Control

98. A controller that produces an output proportional to the magnitude of the error is a:

A. Integral controller

B. Proportional controller

C. Derivative controller

D. On–off controller

99. A resistance temperature detector (RTD) senses temperature through a change in its:

A. Voltage output

B. Colour

C. Physical length

D. Electrical resistance

100. A control valve regulates flow by:

A. Heating the fluid

B. Changing the fluid density

C. Measuring the flow only

D. Varying the flow area through which fluid passes

101. A controller set with too high a gain is most likely to produce:

A. Oscillation or instability

B. A large steady-state offset

C. No response at all

D. Perfect setpoint tracking

Safety, Health, and Environment

102. The narrow band of vapour-in-air concentrations that will support combustion is the:

A. Autoignition zone

B. Dew point

C. Boiling range

D. Flammable range

103. Besides reducing the likelihood of an event, the other way to lower risk is to reduce the:

A. Inspection cost

B. Number of staff

C. Consequence severity

D. Overall plant size

104. A confined space is hazardous principally because of:

A. Limited entry and exit and possible oxygen deficiency

B. Excessive lighting

C. Very high ceilings

D. Open, free ventilation

105. The correct respiratory protection for an oxygen-deficient atmosphere is:

A. A simple dust mask

B. A supplied-air or self-contained breathing apparatus

C. A half-face cartridge respirator

D. No respirator at all

106. The Clean Water Act principally regulates:

A. Air emissions

B. Solid waste disposal

C. Workplace noise

D. Discharges of pollutants to water bodies

Ethics and Professional Practice

107. The paramount obligation expressed in every engineering code of ethics is to:

A. Protect public health, safety, and welfare

B. Maximise the employer's profit

C. Complete projects as fast as possible

D. Minimise the engineer's personal liability

108. An engineer must base professional reports on:

A. Objective, verifiable facts

B. The client's preferred outcome

C. Deliberately optimistic assumptions

D. Unverified rumours

109. An engineer who stands to profit personally from a recommendation must:

A. Proceed silently

B. Exaggerate the benefits

C. Disclose the interest and recuse if necessary

D. Delegate it without explanation

110. Copyright protects:

A. Functional inventions

B. Original works of authorship such as written documents

C. Brand logos alone

D. Confidential formulas alone

Practice Exam 13 — Answer Key and Explanations

1. C — Separating variables gives $dy/y = x\,dx$, which integrates to $\ln y = x^2/2 + C$, or $y = Ce^{(x^2/2)}$. The variable coefficient x produces a Gaussian-type exponential rather than a simple e^x.

2. B — The antiderivative of sin(x) is −cos(x), evaluated from 0 to π as $-\cos \pi + \cos 0 = 1 + 1 = 2$. The full positive half-cycle of the sine encloses an area of two.

3. D — The determinant of any identity matrix is 1, since it is the product of its unit diagonal entries. This reflects that the identity transformation neither scales nor inverts volume.

4. D — By the chain rule, the derivative of $e^{(-x)}$ is $-e^{(-x)}$. The negative sign reflects the decaying exponential's downward slope.

5. C — Factoring gives $(x^2 - 4)/(x - 2) = (x + 2)$, so the limit as $x \to 2$ is 4. Cancelling the common factor removes the removable discontinuity.

6. B — A unit vector has, by definition, a magnitude of exactly 1. It conveys direction alone, with its length normalised to one.

7. C — A standard deck has 13 hearts among 52 cards, so the probability is 13/52 = 0.25. Each of the four suits is equally likely.

8. C — The mean is the sum over the count, (12 + 14 + 16 + 18 + 20)/5 = 80/5 = 16. For evenly spaced data the mean equals the central value.

9. B — The number of combinations is $C(10,2) = 10!/(2!8!) = 45$. Combinations count unordered selections.

10. A — The standard deviation, being the square root of the variance, carries the same units as the original data. This is why it is often preferred over the variance for interpretation.

11. D — The mean of a binomial distribution is $np = 50 \times 0.2 = 10$. This gives the expected number of successes over the trials.

12. A — Power delivered by a constant force at steady velocity is $P = Fv = 200 \times 3 = 600$ W. Power is the rate of doing work.

13. B — Series resistances add directly, $8 + 12 = 20\ \Omega$. The series total always exceeds either individual resistor.

14. B — Newton's second law gives $F = ma = 8 \times 2.5 = 20$ N. Force is the product of mass and acceleration.

15. C — Kinetic energy is $\frac{1}{2}mv^2 = \frac{1}{2} \times 4 \times 10^2 = 200$ J. The square dependence on velocity makes speed the dominant factor.

16. C — A stiffer material resists elastic deformation more strongly, which is quantified by a higher Young's modulus. Stiffness is distinct from strength, which concerns the stress at failure.

17. A — The endurance limit is the stress below which a material can withstand effectively infinite cycles of loading without fatigue failure. Designing below it prevents fatigue cracking in cyclically loaded parts.

18. A — The liquidus line marks the temperature above which an alloy is entirely liquid. Below it, solid begins to crystallise from the melt.

19. B — Paint protects steel by forming a physical barrier that excludes the moisture and oxygen needed for corrosion. Once the barrier is breached, corrosion can proceed beneath it.

20. B — The matrix binds the reinforcing fibres together and transfers applied load between them while protecting them from the environment. The fibres carry most of the load; the matrix distributes it.

21. C — With $[H^+] = 10^{-6}$, the pH is $-\log(10^{-6}) = 6$. This value is slightly acidic, just below neutral.

22. D — Summing atomic masses, C (12) + 4H (4) = 16 g/mol. Molar mass converts between mass and moles in stoichiometry.

23. C — By Boyle's law at constant temperature, halving the volume doubles the pressure, so 2 atm becomes 4 atm. Pressure and volume vary inversely.

24. A — A catalyst accelerates a reaction without being consumed, emerging chemically unchanged at the end. It lowers the activation energy by providing an alternative pathway but is regenerated.

25. C — The two-to-two stoichiometry gives one mole of aluminium chloride per mole of aluminium, so 4 mol of aluminium yields 4 mol of product. Aluminium is the limiting reactant with chlorine in excess.

26. C — Molarity is moles over litres, 0.5/0.250 = 2 M. Concentration relates the amount of solute to the solution volume.

27. D — An ionic bond forms by the transfer of electrons from one atom to another, creating oppositely charged ions that attract. This contrasts with the electron sharing of a covalent bond.

28. A — Cellular respiration captures chemical energy in the form of ATP, the cell's energy currency. ATP then powers the cell's metabolic and mechanical work.

29. B — Reynolds number is $\rho vD/\mu = (1000 \times 1.2 \times 0.05)/0.01 = 6000$. This turbulent value sets the appropriate friction correlation.

30. D — Continuity gives $v_2 = v_1A_1/A_2 = 5 \times (0.08/0.02) = 20$ m/s. The fourfold area reduction quadruples the velocity.

31. D — By Bernoulli's principle, where the velocity rises in the throat the static pressure falls, conserving total head. This pressure drop is the signal a venturi meter measures.

32. C — Hydrostatic pressure is $\rho gh = 1000 \times 9.81 \times 6 = 58{,}860$ Pa ≈ 58.9 kPa. Pressure rises linearly with depth.

33. A — For laminar flow, the friction factor is $64/Re = 64/160 = 0.4$. The inverse dependence on Reynolds number gives high friction at low flow.

34. C — Ideal hydraulic power is $\rho gQH = 1000 \times 9.81 \times 0.05 \times 20 = 9810$ W $= 9.81$ kW. Dividing by efficiency would give the shaft power.

35. C — Volumetric flow is area times velocity, $0.15 \times 4 = 0.6$ m^3/s. This relation sizes ducts for a target throughput.

36. D — A high Reynolds number means inertial forces dominate over viscous forces, characterising turbulent flow. The number is the ratio of these two competing effects.

37. D — A manometer balances the measured pressure against the weight of a liquid column, reading pressure from the height difference. It is a simple, direct standard for low to moderate pressures.

38. C — Carnot efficiency is $1 - T_c/T_h = 1 - 400/800 = 0.50$, or 50%. The temperature ratio alone fixes this ceiling.

39. A — Internal energy change at constant volume is $nC_v\Delta T = 2 \times 25 \times 20 = 1000$ J. The constant-volume heat capacity applies because no work is done.

40. B — The first law gives $\Delta U = Q - W = 600 - 250 = 350$ J. Heat added that is not spent on work raises the internal energy.

41. C — Adiabatic turbine power is $\dot{m}(h_1 - h_2) = 6 \times (3000 - 2600) = 2400$ kW. The enthalpy drop converts directly into shaft work.

42. D — Refrigerator COP is $Q_c/W = 600/240 = 2.5$. The device moves more heat than the work it consumes, the basis of efficient cooling.

43. B — Raoult's law gives the bubble pressure as $0.5 \times 100 + 0.5 \times 60 = 80$ kPa. The total pressure is the mole-fraction-weighted sum of the pure vapour pressures.

44. D — In an isolated system, entropy never decreases, by the second law; it increases for irreversible processes and stays constant only for reversible ones. This sets the direction of spontaneous change.

45. C — A process at constant pressure is isobaric, as distinct from adiabatic, isothermal, or isochoric. Most open-flow and atmospheric processes are isobaric.

46. A — An endothermic reaction absorbs heat, so its heat of reaction is positive. The positive sign denotes energy entering the system.

47. A — A steady-state mass balance sums the inlet streams, $350 + 450 = 800$ kg/h, which must equal the product. Conservation of mass requires the output to match the combined input.

48. B — A solids balance gives $0.20 \times 600 = 0.50 \times L$, so the product is $L = 240$ kg/h. The non-volatile solids fix the product rate.

49. B — At one mole of oxygen per mole of carbon, 3 mol of carbon requires 3 mol. Combustion stoichiometry sets the oxygen demand.

50. C — The combined salt is $0.25 \times 100 + 0.55 \times 100 = 25 + 55 = 80$ kg in 200 kg, giving 40%. A component balance yields the blended composition.

51. B — Conversion is $(600 - 150)/600 = 75\%$. This fraction measures how completely the feed is consumed.

52. D — The recycle ratio is recycle over fresh feed, $800/200 = 4$. It characterises the process's reliance on recycling.

53. D — Sensible heat is $mCp\Delta T = 25 \times 4.18 \times 20 = 2090$ kJ. This relation sizes the heating duty for a temperature change.

54. A — Converting 25% dry basis gives wet basis $= 25/(100 + 25) = 20\%$. The wet basis is the smaller figure because its denominator includes the water.

55. B — The stoichiometry produces three moles of B per two of A, so 4 mol of A yields 6 mol of B. Reaction stoichiometry converts reactant consumed into product formed.

56. B — Percentage excess is $(12.5 - 10)/10 = 25\%$. The surplus oxygen ensures complete combustion.

57. A — In a reactor balance, the maximum product is fixed by the limiting reactant, the one that runs out first. The excess reactants and inerts do not bound the yield.

58. A — Fourier's law gives $Q = kA\Delta T/L = (0.5 \times 4 \times 30)/0.2 = 300$ W. Conductive heat rate scales with conductivity, area, and driving temperature.

59. B — Convective heat rate is $hA\Delta T = 30 \times 3 \times 20 = 1800$ W. The coefficient h reflects how effectively the fluid removes heat.

60. C — Black-body emissive power is proportional to the fourth power of absolute temperature, by the Stefan–Boltzmann law. This steep dependence makes radiation dominant at high temperatures.

61. C — With $\Delta T_1 = 90 - 45 = 45$ °C and $\Delta T_2 = 60 - 25 = 35$ °C, the log-mean is $(45 - 35)/\ln(45/35) = 39.8$ °C. The LMTD is the correct mean driving force, slightly below the arithmetic mean.

62. A — Series thermal resistances add directly, 0.5 + 0.5 = 1.0 K/W. The thermal-circuit analogy makes composite-wall analysis straightforward.

63. B — With negligible wall resistance, $1/U = 1/250 + 1/250 = 0.008$, so $U = 125$ W/m²·K. Two equal series films halve the overall coefficient.

64. D — Exchanger duty is $UA\Delta T = 300 \times 10 \times 20 = 60{,}000$ W = 60 kW. This product of coefficient, area, and driving force sizes the exchanger.

65. A — Heat carried by the bulk motion of a fluid is convection, as opposed to conduction through a stationary medium or radiation through space. Moving the fluid transports thermal energy with it.

66. C — Insulation reduces heat loss by adding conductive thermal resistance in the radial path out of the pipe. A low-conductivity layer impedes the flow of heat to the surroundings.

67. A — Fick's law gives flux = $D \cdot \Delta C/\delta = (2.5 \times 10^{-9} \times 8)/(1 \times 10^{-3}) = 2 \times 10^{-5}$ mol/m²·s. Flux rises with diffusivity and concentration difference and falls with film thickness.

68. A — For the more volatile component, the equilibrium ratio y/x exceeds one, since it concentrates in the vapour. This preferential vaporisation is what drives distillation.

69. B — At total reflux, no product is withdrawn and the column achieves a separation with the minimum number of stages. This sets one bounding limit of column operation.

70. B — For equal volumes with K = 2, the fraction extracted is $K/(K + 1) = 2/3 = 0.67$. A higher distribution coefficient sends more solute to the extract.

71. D — The packed height is HTU × NTU = 0.5 × 8 = 4.0 m. The height of a transfer unit multiplied by the number of units gives the required packing depth.

72. D — Gas solubility in a liquid generally falls as temperature rises, because dissolved gas molecules gain energy to escape. This is why warm water holds less dissolved gas.

73. C — Because azeotropic compositions shift with pressure, an azeotrope can sometimes be broken by changing the operating pressure. Pressure-swing distillation exploits exactly this effect.

74. A — The overall mass-transfer coefficient combines the gas-film and liquid-film resistances in series, since the solute must cross both in turn. The reciprocals of the individual coefficients add.

75. C — The constant-rate drying period ends at the critical moisture content, where the surface can no longer be kept fully wetted. Beyond this point drying enters the slower falling-rate period.

76. B — Stokes' law gives $v = gd^2\Delta\rho/(18\mu) = (9.81 \times (1.5 \times 10^{-4})^2 \times 1000)/(18 \times 10^{-3}) = 1.23 \times 10^{-2}$ m/s. The square dependence on diameter makes settling highly size-sensitive.

77. B — In screening, the oversize is the coarse fraction retained on top of the screen, while the undersize passes through. The aperture size sets the cut between them.

78. A — At minimum fluidisation, the upward pressure drop across the bed just supports its weight per unit area. At this balance point the particles become suspended in the fluid.

79. D — Grinding breaks particles into smaller ones, greatly increasing the specific surface area per unit mass. This larger area speeds dissolution, reaction, and drying.

80. B — First-order decay gives $C = C_0e^{(-kt)} = 2 \times e^{(-0.5 \times 2)} = 2 \times e^{(-1)} = 2 \times 0.368 = 0.74$ mol/L. The concentration falls exponentially at a rate fixed by k.

81. D — For a first-order PFR, conversion is $X = 1 - e^{(-k\tau)} = 1 - e^{(-0.4 \times 5)} = 1 - e^{(-2)} = 0.86$. The plug-flow reactor reaches high conversion efficiently.

82. C — For a first-order CSTR, $\tau = X/[k(1 - X)] = 0.6/(0.3 \times 0.4) = 5$ min. The space time links reactor size to the conversion achieved.

83. B — The zero-order half-life is $C_0/(2k) = 6/(2 \times 1.5) = 2$ min. Unlike first-order, the zero-order half-life depends on the starting concentration.

84. D — At equilibrium the forward and reverse rates balance, so $K = k_{forward}/k_{reverse} = 15/3 = 5$. This links the kinetic constants to the equilibrium position.

85. A — A catalyst speeds the approach to equilibrium but cannot change the equilibrium conversion, since it accelerates forward and reverse reactions equally. The final equilibrium is set by thermodynamics, not kinetics.

86. B — A rate constant with units of mol/(L·s) corresponds to a zero-order reaction, whose rate equals k independent of concentration. The units of k reveal the overall reaction order.

87. D — Future worth is $P(1 + i)^n = 10{,}000 \times 1.07^6 = 10{,}000 \times 1.5007 = \$15{,}007$. Compounding grows the sum forward at the stated rate.

88. C — The six-tenths rule gives $200{,}000 \times (25/5)^{0.6} = 200{,}000 \times 2.627 = \$525{,}000$. A fivefold capacity increase raises cost only about 2.6-fold, the economy of scale.

89. D — Simple payback is capital over annual return, 1,200,000/300,000 = 4 years. The measure is quick but ignores the time value of money.

90. D — Present worth of the annuity is 2500 × 7.5361 = $18,840. The annuity factor sums the discounted value of all twelve payments.

91. B — The block flow diagram is the simplest representation, showing major process sections as connected blocks. It communicates the overall concept before equipment detail is added.

92. A — For a reversible exothermic reaction, the optimum temperature balances faster kinetics at high temperature against the higher equilibrium conversion favoured at low temperature. This trade-off defines the optimal operating curve.

93. C — Updating with the cost index gives 150,000 × (1000/750) = $200,000. The index ratio corrects the historical cost for inflation.

94. A — A plate-and-frame exchanger packs a very large heat-transfer area into a compact volume through its stacked thin plates. This makes it well suited to duties where space is limited.

95. D — A centrifugal pump is the standard choice for clean liquids at high flow and low to moderate head. Its simple rotating design handles large throughputs efficiently.

96. D — Stainless steel resists concentrated nitric acid through a stable passive oxide film, unlike mild steel or copper, which corrode. Correct material selection here prevents a hazardous failure.

97. A — A rupture disc is chosen when a fast-acting, non-reclosing relief device is needed, opening fully and instantly at its burst pressure. It suits rapid overpressure events but does not reseat afterwards.

98. B — A proportional controller produces an output proportional to the magnitude of the error. Its action is immediate but generally leaves a residual steady-state offset.

99. D — A resistance temperature detector senses temperature through the change in its electrical resistance, which rises predictably with temperature. This gives a stable and accurate measurement.

100. D — A control valve regulates flow by varying the open area through which the fluid passes, changing the resistance to flow. The actuator positions the valve in response to the controller.

101. A — Too high a controller gain over-corrects each error and tends to drive the loop into oscillation or instability. Proper tuning keeps the response fast yet stable.

102. D — The flammable range is the band of vapour-in-air concentrations, between the lower and upper flammability limits, that will support combustion. Outside this band the mixture is too lean or too rich to burn.

103. C — Risk is the product of likelihood and consequence, so risk can be reduced either by lowering the probability or by reducing the consequence severity. Addressing both gives the most robust risk reduction.

104. A — A confined space is hazardous chiefly because its limited entry and exit hamper escape and rescue, and its poor ventilation can create an oxygen-deficient or toxic atmosphere. These combined factors make confined-space entry a high-risk activity.

105. B — An oxygen-deficient atmosphere requires a supplied-air or self-contained breathing apparatus that provides its own air, since filtering respirators cannot add oxygen. Air-purifying masks are useless when the surrounding air lacks oxygen.

106. D — The Clean Water Act principally regulates the discharge of pollutants into water bodies, setting limits on effluent streams. Compliance governs a plant's wastewater treatment and outfall permits.

107. A — Every engineering code of ethics holds the protection of public health, safety, and welfare as the paramount duty. This obligation takes precedence over duties to employer or client.

108. A — Professional reports must rest on objective, verifiable facts rather than on a desired conclusion or unsupported claims. Honest reporting underpins the trust placed in engineering work.

109. C — An engineer who would profit personally from a recommendation has a conflict of interest that must be disclosed, with recusal where the conflict is significant. Transparency preserves the integrity of professional judgement.

110. B — Copyright protects original works of authorship, such as written documents, drawings, and software, fixed in a tangible form. Functional inventions are instead the domain of patents.