PRACTICE EXAM 9: FE CHEMICAL SIMULATION (110 QUESTIONS)

Mathematics

1. Solve dy/dx = 2x with the initial condition y(1) = 3. What is y(x)?

A. $y = x^2 + 2$

B. $y = 2x^2$

C. $y = x^2 + 3$

D. $y = 2x + 1$

2. Evaluate the integral of 1/x from x = 1 to x = e.

A. e

B. 0

C. 1

D. e − 1

3. What are the dimensions of the transpose of a 3 × 5 matrix?

A. 5 × 3

B. 3 × 5

C. 5 × 5

D. 3 × 3

4. What is the determinant of the matrix [[2, 1], [4, 3]]?

A. 10

B. 2

C. 6

D. 4

5. Evaluate the limit of $(3x^2 + 2x)/(x^2 + 1)$ as x approaches infinity.

A. Infinity

B. 3

C. 2

D. 0

6. What is the derivative of e^(2x) with respect to x?

A. e^(2x)

B. e^x

C. 2e^(2x)

D. 2x·e^(2x)

Probability and Statistics

7. What is the variance of the data set 4, 4, 4, and 4?

A. 0

B. 4

C. 16

D. 1

8. An event has a probability of 0.35. What is the probability that it does not occur?

A. 0.35

B. 0.65

C. 1.35

D. 0.30

9. In how many ways can 2 items be arranged in order from a set of 5 distinct items?

A. 10

B. 25

C. 120

D. 20

10. For a normal distribution, what is the probability that a value falls below the mean?

A. 0.68

B. 0.5

C. 1.0

D. 0.34

11. A game pays $10 with probability 0.2 and nothing otherwise. What is the expected payout?

A. $10

B. $2

C. $8

D. $5

Engineering Sciences

12. A device operates at 120 V drawing a current of 5 A. What power does it consume?

A. 600 W

B. 24 W

C. 125 W

D. 115 W

13. A 5 kg mass is raised to a height of 10 m. What is its gain in potential energy?

A. 50 J

B. 98 J

C. 490 J

D. 981 J

14. A tangential force of 50 N is applied at the rim of a wheel of radius 0.2 m. What is the torque?

A. 250 N·m

B. 10 N·m

C. 0.004 N·m

D. 50 N·m

15. A 24 V source is connected across an 8 Ω resistor. What current flows?

A. 192 A

B. 3 A

C. 0.33 A

D. 8 A

Materials Science

16. Young's modulus is expressed in which units?

A. Pascals (Pa)

B. Newtons (N)

C. Joules (J)

D. It is dimensionless

17. Annealing a cold-worked metal serves chiefly to:

A. Harden it and increase its brittleness

B. Soften it and relieve internal stresses

C. Melt it completely

D. Increase its density permanently

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

A. Lowers its melting point

B. Makes it more soluble

C. Increases its electrical conductivity

D. Increases its rigidity and reduces flexibility

19. A fibre-reinforced composite derives its strength mainly from:

A. The matrix carrying the load alone

B. The fibres carrying most of the load

C. The porosity between the layers

D. The surface coating only

20. The eutectic point on a binary phase diagram corresponds to the composition that:

A. Has the highest melting temperature

B. Contains only one component

C. Melts and solidifies at the lowest temperature

D. Is always a pure metal

Chemistry and Biology

21. Which of the following is a strong acid?

A. Acetic acid

B. Carbonic acid

C. Citric acid

D. Hydrochloric acid

22. How many moles are present in 36 g of water (molar mass 18 g/mol)?

A. 2 mol

B. 1 mol

C. 18 mol

D. 0.5 mol

23. At constant volume, what is the effect of doubling the absolute temperature of a fixed quantity of gas?

A. It halves the pressure

B. It produces no change

C. It doubles the pressure

D. It quadruples the pressure

24. An exothermic reaction has an enthalpy change that is:

A. Negative

B. Positive

C. Zero

D. Always equal to its entropy change

25. For 2A + B → C, a reactor holds 4 mol of A and 3 mol of B. How many moles of C can form?

A. 2 mol

B. 4 mol

C. 3 mol

D. 1 mol

26. What effect does adding a catalyst have on a system already at equilibrium?

A. It shifts the equilibrium toward products

B. It shifts the equilibrium toward reactants

C. It increases the equilibrium constant

D. It does not change the equilibrium position

27. What is the pH of a neutral aqueous solution at 25 °C?

A. 0

B. 14

C. 7

D. 1

28. Enzyme-catalysed activity is greatest at the enzyme's:

A. Freezing point

B. Boiling point

C. Optimum temperature and pH

D. Zero substrate concentration

Fluid Mechanics

29. A fluid (density 1000 kg/m^3, viscosity 1×10^{-3} Pa·s) flows at 3 m/s through a 0.02 m pipe. What is the Reynolds number?

A. 600

B. 6000

C. 30000

D. 60000

30. Incompressible flow passes from a pipe into a section three times the area. If the upstream velocity is 6 m/s, what is the downstream velocity?

A. 18 m/s

B. 6 m/s

C. 2 m/s

D. 3 m/s

31. A water jet leaves a nozzle at 14 m/s and rises vertically. Neglecting losses, to what height does it rise?

A. 10 m

B. 14 m

C. 1.4 m

D. 28 m

32. What is the hydrostatic pressure at a depth of 5 m in water (density 1000 kg/m^3)?

A. 49 kPa

B. 5 kPa

C. 490 kPa

D. 4.9 kPa

33. For laminar pipe flow at a Reynolds number of 320, what is the Darcy friction factor?

A. 0.02

B. 64

C. 2.0

D. 0.2

34. A pump delivers 0.05 m^3/s of water against a head of 10 m. What is the ideal hydraulic power?

A. 0.49 kW

B. 49 kW

C. 490 W

D. 4.9 kW

35. A fluid flows at 2.5 m/s through a duct of cross-sectional area 0.1 m^2. What is the volumetric flow rate?

A. 0.04 m^3/s

B. 0.25 m^3/s

C. 25 m^3/s

D. 2.5 m^3/s

36. At high Reynolds number, the drag force on a body is proportional to:

A. The square of the velocity

B. The velocity directly

C. The inverse of the velocity

D. The cube of the velocity

37. Surface tension is the property chiefly responsible for:

A. Turbulent mixing in pipes

B. Cavitation in pumps

C. Frictional pressure drop

D. Capillary rise in a narrow tube

Thermodynamics

38. A Carnot engine operates between 500 K and 250 K. What is its maximum efficiency?

A. 25%

B. 50%

C. 75%

D. 33%

39. Two moles of an ideal gas (C_v = 21 J/mol·K) are heated by 40 K at constant volume. What is the change in internal energy?

A. 1680 J

B. 840 J

C. 3360 J

D. 168 J

40. A closed system absorbs 800 J of heat while doing 300 J of work on its surroundings. What is the change in internal energy?

A. 1100 J

B. −500 J

C. 500 J

D. 800 J

41. Steam enters an adiabatic turbine at 3000 kJ/kg and leaves at 2500 kJ/kg, flowing at 4 kg/s. What is the shaft power?

A. 2000 kW

B. 500 kW

C. 1000 kW

D. 2500 kW

42. A refrigerator removes 400 W from the cold space while consuming 160 W of work. What is its coefficient of performance?

A. 4

B. 2.5

C. 0.4

D. 1.6

43. An equimolar liquid mixture of A (pure vapour pressure 150 kPa) and B (50 kPa) follows Raoult's law. What is the bubble-point pressure?

A. 50 kPa

B. 100 kPa

C. 150 kPa

D. 200 kPa

44. In any spontaneous process within an isolated system, the entropy:

A. Decreases

B. Stays constant

C. Becomes zero

D. Increases

45. A reaction has $\Delta H = 40{,}000$ J/mol and $\Delta S = 100$ J/mol·K. At what temperature does equilibrium occur ($\Delta G = 0$)?

A. 400 K

B. 4000 K

C. 250 K

D. 100 K

46. When an ideal gas is throttled adiabatically through a valve, its temperature:

A. Rises significantly

B. Stays constant

C. Falls sharply

D. Doubles

Material and Energy Balances

47. Two feed streams of 300 kg/h and 500 kg/h combine, and a 700 kg/h product is withdrawn. What is the waste stream flow at steady state?

A. 800 kg/h

B. 700 kg/h

C. 100 kg/h

D. 200 kg/h

48. An evaporator concentrates 1500 kg/h of an 8% solids feed to a 24% solids product. How much water is evaporated?

A. 500 kg/h

B. 120 kg/h

C. 480 kg/h

D. 1000 kg/h

49. Complete combustion of methane requires 2 mol of oxygen per mole. How many moles of oxygen are needed for 3 mol of methane?

A. 2 mol

B. 3 mol

C. 6 mol

D. 12 mol

50. A 200 kg stream of 20% salt is mixed with a 300 kg stream of 40% salt. What is the salt content of the mixture?

A. 30%

B. 32%

C. 60%

D. 20%

51. A reactor is fed 200 mol of A, of which 50 mol leaves unreacted. What is the conversion?

A. 25%

B. 50%

C. 100%

D. 75%

52. A process recycles 900 mol/h and receives a fresh feed of 300 mol/h. What is the recycle ratio?

A. 0.33

B. 1.5

C. 3

D. 1200

53. How much heat is required to raise 20 kg of a fluid (C_p = 2.5 kJ/kg·K) by 30 °C?

A. 1500 kJ

B. 750 kJ

C. 3000 kJ

D. 150 kJ

54. A 100 kg batch of solid contains 40% moisture on a wet basis. What is the mass of dry solid?

A. 60 kg

B. 40 kg

C. 100 kg

D. 24 kg

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

A. 4 mol

B. 8 mol

C. 12 mol

D. 6 mol

56. A burner needs 3 mol of oxygen stoichiometrically but is supplied with 3.75 mol. What is the percentage excess oxygen?

A. 20%

B. 25%

C. 75%

D. 12.5%

57. The minimum quantity of air required for complete combustion of a fuel is termed the:

A. Stoichiometric air

B. Excess air

C. Flue air

D. Primary air only

Heat Transfer

58. A 0.2 m thick wall ($k = 1.5$ W/m·K, area 4 m²) has a 50 °C temperature difference across it. What is the conductive heat rate?

A. 300 W

B. 600 W

C. 1500 W

D. 3000 W

59. A 3 m² surface transfers heat by convection with $h = 40$ W/m²·K and a temperature difference of 25 °C. What is the heat rate?

A. 750 W

B. 1000 W

C. 1500 W

D. 3000 W

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

A. 9×

B. 81×

C. 27×

D. 3×

61. In a counter-current exchanger, the hot stream cools from 90 °C to 50 °C while the cold stream warms from 20 °C to 40 °C. What is the log-mean temperature difference?

A. 40 °C

B. 35 °C

C. 39.2 °C

D. 50 °C

62. Two wall layers have thermal resistances of 0.05 K/W and 0.15 K/W in series. What is the total resistance?

A. 0.0375 K/W

B. 0.1 K/W

C. 0.2 K/W

D. 0.3 K/W

63. Two convective films of 200 and 300 $W/m^2 \cdot K$ act in series with negligible wall resistance. What is the overall coefficient U?

A. 120 $W/m^2 \cdot K$

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

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

D. 100 $W/m^2 \cdot K$

64. An exchanger has $U = 300\ W/m^2 \cdot K$, area 8 m^2, and a log-mean temperature difference of 25 °C. What is the heat duty?

A. 6 kW

B. 24 kW

C. 30 kW

D. 60 kW

65. Which of the following is the best thermal insulator?

A. Aluminium

B. Fibreglass

C. Copper

D. Steel

66. An ideal black body is defined by its ability to:

A. Absorb none of the incident radiation

B. Absorb half of the incident radiation

C. Absorb only visible light

D. Absorb all incident radiation

Mass Transfer and Separation

67. A species diffuses through a 1 mm film with $D = 2 \times 10^{-9}$ m^2/s and a concentration difference of 15 mol/m^3. What is the molar flux?

A. 3×10^{-5} $mol/m^2 \cdot s$

B. 3×10^{-8} $mol/m^2 \cdot s$

C. 1.5×10^{-5} $mol/m^2 \cdot s$

D. 3×10^{-3} $mol/m^2 \cdot s$

68. For a relative volatility of 4, what vapour composition is in equilibrium with a liquid of mole fraction 0.25?

A. 0.25

B. 0.57

C. 0.75

D. 1.0

69. What is the effect of raising the reflux ratio above its minimum value?

A. It increases the number of stages required

B. It reduces the number of stages required

C. It has no effect on the stages

D. It eliminates the condenser

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. 0.33

C. 0.67

D. 0.25

71. A packed column has an HTU of 0.6 m and requires 4 transfer units. What is the packed height?

A. 2.4 m

B. 4.6 m

C. 0.6 m

D. 6.7 m

72. Mass transfer in an absorber ceases when:

A. The liquid reaches equilibrium with the gas

B. The temperature begins to rise

C. The pressure has doubled

D. Only the gas flow stops

73. A feed entering a distillation column as a saturated vapour has a q-value of:

A. 1

B. 0.5

C. Greater than 1

D. 0

74. Ultrafiltration separates dissolved and suspended species mainly on the basis of:

A. Their boiling point

B. Their density

C. Their molecular size

D. Their electric charge only

75. The individual gas-film and liquid-film coefficients combine into an overall mass-transfer coefficient by adding:

A. Their coefficients directly

B. Their velocities

C. Their areas

D. Their resistances in series

Solids Handling

76. A 150 μm particle ($\Delta\rho = 2000\ kg/m^3$) settles in a fluid of viscosity 1×10^{-3} Pa·s. What is its Stokes' law terminal velocity?

A. 1.2×10^{-2} m/s

B. 6.1×10^{-3} m/s

C. 4.9×10^{-2} m/s

D. 2.45×10^{-2} m/s

77. Screening efficiency tends to fall when:

A. The feed rate is very low

B. The particles are very coarse only

C. The screen is overloaded with feed

D. The aperture is too large

78. A screw conveyor is best suited to:

A. Moving bulk solids over short distances

B. Pumping low-viscosity liquids

C. Transporting gases

D. Long-distance slurry pipelines

79. The Rittinger, Kick, and Bond laws all describe:

A. The settling velocity of particles

B. The onset of fluidisation

C. The rate of filtration

D. The energy required for size reduction

Chemical Reaction Engineering

80. A first-order reaction ($k = 0.3\ min^{-1}$) starts at 2 mol/L. What is the concentration after 5 minutes, using $C = C_0e^{(-kt)}$?

A. 0.45 mol/L

B. 0.22 mol/L

C. 1.0 mol/L

D. 0.10 mol/L

81. A first-order reaction ($k = 0.25\ min^{-1}$) reaches 80% conversion in a CSTR. What space time is required?

A. 4 min

B. 8 min

C. 16 min

D. 6.4 min

82. A first-order reaction has a rate constant of $0.0231\ min^{-1}$. What is its half-life?

A. 30 min

B. 15 min

C. 60 min

D. 0.69 min

83. A rate constant with units of reciprocal seconds (1/s) corresponds to a reaction of which order?

A. Zero order

B. First order

C. Second order

D. Third order

84. For the reversible reaction A ⇌ B, the forward rate constant is 8 and the reverse is 2. What is the equilibrium constant?

A. 16

B. 0.25

C. 2

D. 4

85. A catalyst poison deactivates a catalyst by:

A. Raising the operating temperature

B. Blocking the active sites

C. Increasing the surface area

D. Lowering the activation energy

86. A reaction yields 90 mol of desired product and 30 mol of by-product. What is the selectivity?

A. 3.0

B. 0.33

C. 90

D. 30

Engineering Economics

87. What is the future worth of $8,000 invested for 6 years at 5% interest ($1.05^6 = 1.3401$)?

A. $9,200

B. $8,400

C. $10,721

D. $12,000

88. What is the present worth of $15,000 to be received in 4 years at 8% interest ($1.08^4 = 1.3605$)?

A. $11,025

B. $13,889

C. $15,000

D. $20,407

89. A $120,000 asset is depreciated evenly over 10 years to zero salvage. What is the annual depreciation?

A. $10,000

B. $6,000

C. $24,000

D. $12,000

90. A project has a rate of return of 15% against a minimum acceptable rate of return of 12%. The project should be:

A. Rejected

B. Deferred indefinitely

C. Accepted

D. Cancelled

Process Design

91. Which engineering diagram shows every instrument and control loop in a process?

A. The block flow diagram

B. The process flow diagram

C. The plot plan

D. The piping and instrumentation diagram

92. Increasing the area of a heat exchanger lowers its operating cost but:

A. Raises the capital cost

B. Lowers the capital cost

C. Has no effect on cost

D. Reduces the heat duty

93. Equipment that cost $80,000 at a cost index of 400 is re-estimated at a current index of 600. What is the updated cost?

A. $53,300

B. $80,000

C. $96,000

D. $120,000

94. For cryogenic (very low temperature) service, a suitable material of construction is:

A. Ordinary carbon steel

B. Cast iron

C. Austenitic stainless steel

D. Grey iron

95. For a low-flow, high-precision metering duty, the preferred pump type is:

A. A large centrifugal pump

B. An axial-flow pump

C. A positive-displacement metering pump

D. A jet pump

96. When mixing is the controlling factor, equipment scale-up holds constant the:

A. Power per unit volume

B. Tank height only

C. Impeller diameter only

D. Fluid colour

97. A pressure-relief valve is sized to handle the:

A. Normal operating flow

B. Average daily flow

C. Half-maximum flow

D. Worst credible overpressure scenario

Process Control

98. A system with a larger time constant responds to a change:

A. Instantly

B. Faster

C. More slowly

D. Unpredictably

99. In most control loops, the final control element is the:

A. Sensor

B. Control valve

C. Transmitter

D. Controller

100. Feedforward control fundamentally requires:

A. Measurement of the output only

B. Measurement of the disturbance variable

C. No measurement at all

D. A manual override

101. Excessive integral action in a controller tends to produce:

A. A persistent steady-state offset

B. An instantaneous response

C. Zero controller gain

D. Oscillation and overshoot

Safety, Health, and Environment

102. The autoignition temperature of a substance is the temperature at which it:

A. Boils at atmospheric pressure

B. First forms a flammable vapour

C. Ignites without an external ignition source

D. Reaches its flash point

103. Operating a vapour–air mixture below its lower explosive limit means the mixture is:

A. Too rich to ignite

B. At its peak hazard

C. Too lean to ignite

D. Above its autoignition point

104. The IDLH value of a contaminant represents a concentration that is:

A. The legal 8-hour average exposure

B. A safe long-term level

C. The odour-detection threshold

D. Immediately dangerous to life and health

105. Under the standard classification, a Class B fire involves:

A. Ordinary combustibles

B. Energised electrical equipment

C. Combustible metals

D. Flammable liquids

106. The most preferred option in the waste-management hierarchy is:

A. Landfill disposal

B. Source reduction

C. Incineration

D. Long-term storage

Ethics and Professional Practice

107. When asked to certify work that does not meet code requirements, an engineer should:

A. Certify it to retain the client

B. Certify it with a verbal warning

C. Delegate the certification to a junior

D. Refuse to certify non-compliant work

108. An engineer asked to take on work outside their area of expertise should:

A. Proceed and learn on the job

B. Accept it and hide the knowledge gap

C. Subcontract it without disclosure

D. Decline or obtain qualified assistance

109. Green engineering aims primarily to:

A. Maximise end-of-pipe treatment

B. Prevent pollution at the source

C. Increase raw-material consumption

D. Disregard lifecycle impacts

110. An engineer who owns shares in a vendor being evaluated for a contract must:

A. Conceal the financial interest

B. Disclose the financial interest to the relevant parties

C. Sell the shares quietly after the decision

D. Proceed without any comment

Practice Exam 9 — Answer Key and Explanations

1. A — Integrating $dy/dx = 2x$ gives $y = x^2 + C$; applying $y(1) = 3$ sets $3 = 1 + C$, so $C = 2$ and $y = x^2 + 2$. The initial condition pins down the constant that the general solution leaves free.

2. C — The antiderivative of $1/x$ is $\ln(x)$, evaluated from 1 to e as $\ln(e) - \ln(1) = 1 - 0 = 1$. This logarithmic integral arises whenever a rate is inversely proportional to the variable.

3. A — Transposing swaps rows and columns, so a 3 × 5 matrix becomes 5 × 3. The transpose is fundamental in least-squares and symmetric-matrix operations.

4. B — The 2 × 2 determinant is $ad - bc = (2)(3) - (1)(4) = 6 - 4 = 2$. A nonzero value confirms the matrix is invertible.

5. B — As x grows large, the ratio approaches the quotient of the leading coefficients, 3/1 = 3. The lower-order terms become negligible at infinity.

6. C — By the chain rule, $d/dx\ e^{(2x)} = 2e^{(2x)}$. The exponent's derivative multiplies the exponential, the basis of growth- and decay-rate analysis.

7. A — With every value identical, there is no spread, so the variance is 0. Variance measures dispersion about the mean, which vanishes when all data coincide.

8. B — The complement rule gives P(not A) = 1 − 0.35 = 0.65. Complements simplify "at least one" and failure-probability calculations.

9. D — The number of ordered arrangements is P(5,2) = 5 × 4 = 20. Permutations count selections where order matters, unlike combinations.

10. B — A normal distribution is symmetric about its mean, so exactly half the probability lies below it, 0.5. This symmetry underlies the use of z-scores.

11. B — Expected payout is the probability-weighted average, 0.2 × 10 + 0.8 × 0 = $2. Expectation gives the long-run average outcome of a random payout.

12. A — Electrical power is P = VI = 120 × 5 = 600 W. This product sizes circuits and the cooling required for electrical loads.

13. C — Potential energy gained is mgh = 5 × 9.81 × 10 = 490.5 J. This stored energy equals the work done lifting the mass.

14. B — Torque is force times radius, 50 × 0.2 = 10 N·m. This moment about the axle determines the rotational effect of the applied force.

15. B — Ohm's law gives I = V/R = 24/8 = 3 A. Current is proportional to voltage and inversely proportional to resistance.

16. A — Young's modulus is a ratio of stress to strain, and since strain is dimensionless, it carries the units of stress, pascals. This places it in the same units as pressure.

17. B — Annealing heats a cold-worked metal to soften it and relieve internal residual stresses through recovery and recrystallisation. It restores ductility lost during forming.

18. D — Cross-linking ties polymer chains together, increasing rigidity and reducing flexibility. Heavily cross-linked thermosets become hard and infusible.

19. B — In a fibre-reinforced composite the strong, stiff fibres carry most of the load, while the matrix transfers stress between them and holds them in place. This division of roles gives composites their high strength-to-weight ratio.

20. C — The eutectic point is the composition that melts and solidifies at the single lowest temperature of the system. This low-melting behaviour is exploited in solders and casting alloys.

21. D — Hydrochloric acid is a strong acid that dissociates completely in water, unlike the weak organic acids listed. Complete dissociation gives it a low pH at modest concentration.

22. A — Moles equal mass over molar mass, 36/18 = 2 mol. This conversion is the basis of all stoichiometric work.

23. C — At constant volume, Gay-Lussac's law makes pressure proportional to absolute temperature, so doubling the temperature doubles the pressure. This relation governs the pressure rise in sealed, heated vessels.

24. A — An exothermic reaction releases heat, so its enthalpy change is negative. The negative sign denotes energy leaving the system to the surroundings.

25. A — With 4 mol of A and a 2:1 requirement, A can pair with only 2 mol of B, leaving B in excess and making A the limiting reactant; the product is 2 mol. The limiting reactant caps the achievable yield.

26. D — A catalyst speeds both the forward and reverse reactions equally, so it does not change the equilibrium position. It only shortens the time taken to reach that equilibrium.

27. C — A neutral aqueous solution at 25 °C has equal hydrogen and hydroxide ion concentrations, giving a pH of 7. This is the reference point separating acidic and basic solutions.

28. C — Enzyme activity peaks at the enzyme's optimum temperature and pH, where its three-dimensional structure is best maintained. Departures in either direction reduce activity by altering the active site.

29. D — Reynolds number is $\rho vD/\mu = (1000 \times 3 \times 0.02)/0.001 = 60{,}000$. This turbulent value sets the appropriate friction correlation.

30. C — Continuity gives $v_2 = v_1A_1/A_2 = 6/3 = 2$ m/s. Tripling the area cuts the velocity to a third, conserving volumetric flow.

31. A — Converting all kinetic energy to potential energy gives $h = v^2/2g = 14^2/(2 \times 9.81) = 196/19.62 \approx 10$ m. This is the Bernoulli result for a frictionless rising jet.

32. A — Hydrostatic pressure is $\rho gh = 1000 \times 9.81 \times 5 = 49{,}050$ Pa ≈ 49 kPa. Pressure rises linearly with depth in a static fluid.

33. D — For laminar flow, the friction factor is $64/Re = 64/320 = 0.2$. The strong inverse dependence on Reynolds number means high friction at low flow.

34. D — Ideal hydraulic power is $\rho gQH = 1000 \times 9.81 \times 0.05 \times 10 = 4905$ W ≈ 4.9 kW. Dividing by efficiency would give the actual shaft power required.

35. B — Volumetric flow rate is area times velocity, $0.1 \times 2.5 = 0.25$ m^3/s. This relation sizes ducts to carry a target throughput.

36. A — At high Reynolds number, drag force is proportional to the square of velocity, since inertial effects dominate. This quadratic dependence drives the steep rise of drag with speed.

37. D — Surface tension drives capillary rise, pulling liquid up a narrow tube against gravity. It arises from the cohesive forces at the liquid surface.

38. B — Carnot efficiency is $1 - T_c/T_h = 1 - 250/500 = 0.50$, or 50%. The temperature ratio alone fixes this upper limit.

39. A — Internal energy change at constant volume is $nC_v\Delta T = 2 \times 21 \times 40 = 1680$ J. The constant-volume heat capacity applies since no expansion work is done.

40. C — The first law gives $\Delta U = Q - W = 800 - 300 = 500$ J. Heat added that is not spent on work raises the internal energy.

41. A — Adiabatic turbine power is $\dot{m}(h_1 - h_2) = 4 \times (3000 - 2500) = 2000$ kW. The enthalpy drop converts directly into shaft work.

42. B — Refrigerator COP is $Q_c/W = 400/160 = 2.5$. 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 $0.5 \times 150 + 0.5 \times 50 = 100$ kPa. The total pressure is the mole-fraction-weighted sum of the pure-component vapour pressures.

44. D — In any spontaneous process within an isolated system, the entropy increases, reaching a maximum at equilibrium. This is the entropy statement of the second law.

45. A — Setting $\Delta G = \Delta H - T\Delta S = 0$ gives $T = \Delta H/\Delta S = 40{,}000/100 = 400$ K. At this temperature the reaction is poised at equilibrium between enthalpy and entropy effects.

46. B — For an ideal gas, enthalpy depends only on temperature, and since throttling conserves enthalpy, the temperature stays constant. Real gases show a temperature change because their enthalpy also depends on pressure.

47. C — A steady-state mass balance gives waste = $300 + 500 - 700 = 100$ kg/h. Conservation of mass closes the balance around the unit.

48. D — A solids balance gives $0.08 \times 1500 = 0.24 \times L$, so $L = 500$ kg/h of product, and water evaporated $= 1500 - 500 = 1000$ kg/h. The non-volatile solids fix the product rate.

49. C — At 2 mol of oxygen per mole of methane, 3 mol of methane needs $3 \times 2 = 6$ mol of oxygen. Combustion stoichiometry sets the oxygen demand.

50. B — The combined salt is $0.20 \times 200 + 0.40 \times 300 = 40 + 120 = 160$ kg in 500 kg, giving 32%. A component balance yields the blended composition.

51. D — Conversion is $(200 - 50)/200 = 75\%$. This fraction measures how completely the reactor consumes its feed.

52. C — The recycle ratio is recycle over fresh feed, $900/300 = 3$. It characterises how heavily the process relies on recycling.

53. A — Sensible heat is $mC_p\Delta T = 20 \times 2.5 \times 30 = 1500$ kJ. This relation sizes the heating duty for a temperature rise without phase change.

54. A — At 40% moisture wet basis, the dry solid is 60% of the 100 kg batch, so 60 kg. The dry mass remains constant through any subsequent drying.

55. C — The stoichiometry produces three moles of C per mole of A, so 4 mol of A yields 12 mol of C. Reaction stoichiometry converts reactant consumed into product formed.

56. B — Percentage excess is $(3.75 - 3)/3 = 25\%$. The surplus oxygen drives combustion to completion and passes through unreacted.

57. A — The minimum air needed for complete combustion is the stoichiometric, or theoretical, air. Any air supplied beyond this is the excess air.

58. C — Fourier's law gives $Q = kA\Delta T/L = (1.5 \times 4 \times 50)/0.2 = 1500$ W. Conductive heat rate scales with conductivity, area, and driving temperature.

59. D — Convective heat rate is $hA\Delta T = 40 \times 3 \times 25 = 3000$ W. The coefficient h captures the effectiveness of fluid motion in removing heat.

60. B — Radiated power scales with the fourth power of absolute temperature, so tripling T raises emission by $3^4 = 81$ times. This steep dependence dominates at high temperatures.

61. C — With $\Delta T_1 = 50$ °C and $\Delta T_2 = 30$ °C, the log-mean is $(50 - 30)/\ln(50/30) = 20/0.511 = 39.2$ °C. The LMTD, not the arithmetic mean of 40 °C, is the correct driving force.

62. C — Series resistances add directly, 0.05 + 0.15 = 0.2 K/W. The thermal-circuit analogy makes composite-wall analysis straightforward.

63. A — With negligible wall resistance, $1/U = 1/200 + 1/300 = 0.00833$, so $U = 120$ W/m²·K. The overall coefficient is smaller than either film coefficient.

64. D — Exchanger duty is $UA\Delta T = 300 \times 8 \times 25 = 60{,}000$ W = 60 kW. This product of coefficient, area, and driving force sizes the exchanger.

65. B — Fibreglass is the best insulator listed, with very low thermal conductivity, whereas aluminium, copper, and steel are good conductors. Trapped air within the fibres limits heat conduction.

66. D — An ideal black body absorbs all incident radiation, reflecting and transmitting none. This perfect absorber is also the perfect emitter, the reference for radiation calculations.

67. A — Fick's law gives flux $= D \cdot \Delta C/\delta = (2 \times 10^{-9} \times 15)/(1 \times 10^{-3}) = 3 \times 10^{-5}$ mol/m²·s. Flux rises with diffusivity and concentration difference and falls with film thickness.

68. B — Using $y = \alpha x/[1 + (\alpha - 1)x] = (4 \times 0.25)/(1 + 3 \times 0.25) = 1.0/1.75 = 0.57$. The vapour is enriched in the volatile component relative to the liquid.

69. B — Raising the reflux ratio above its minimum reduces the number of stages a column needs, trading more energy for less equipment. Real columns operate above minimum reflux for this reason.

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

71. A — Packed height is HTU × NTU = 0.6 × 4 = 2.4 m. The separation difficulty and the packing efficiency together fix the height.

72. A — Absorption ceases when the liquid reaches equilibrium with the gas, eliminating the concentration driving force. At equilibrium no further net transfer occurs.

73. D — A feed entering as a saturated vapour has a q-value of 0, since none of it is liquid. The q-value fixes the slope of the feed line on a McCabe–Thiele diagram.

74. C — Ultrafiltration separates species primarily by molecular size, retaining larger molecules while passing smaller ones and solvent. The membrane's pore size sets the cut-off.

75. D — The overall mass-transfer coefficient is found by adding the gas-film and liquid-film resistances in series, not the coefficients directly. The film with the larger resistance controls the rate.

76. D — Stokes' law gives $v = gd^2\Delta\rho/(18\mu) = (9.81 \times (1.5 \times 10^{-4})^2 \times 2000)/(18 \times 10^{-3}) = 2.45 \times 10^{-2}$ m/s. The square dependence on diameter makes settling velocity highly size-sensitive.

77. C — Screening efficiency falls when the screen is overloaded, since the excess bed depth prevents fine particles from reaching and passing the apertures. Operating below capacity preserves efficiency.

78. A — A screw conveyor suits moving bulk solids over relatively short distances, using a rotating helical screw within a trough. It handles granular and powdered materials reliably.

79. D — The Rittinger, Kick, and Bond laws each relate the energy input to the degree of size reduction in crushing and grinding. They differ in how that energy scales with particle size.

80. A — First-order decay gives $C = C_0e^{(-kt)} = 2 \times e^{(-0.3 \times 5)} = 2 \times e^{(-1.5)} = 2 \times 0.223 = 0.45$ mol/L. The concentration falls exponentially at a rate fixed by k.

81. C — For a first-order CSTR, $\tau = X/[k(1 - X)] = 0.8/(0.25 \times 0.2) = 16$ min. The CSTR operates at the low exit concentration, so it requires a long residence time for high conversion.

82. A — The first-order half-life is $0.693/k = 0.693/0.0231 = 30$ min. This half-life is independent of concentration, the signature of first-order kinetics.

83. B — A rate constant with units of reciprocal time (1/s) corresponds to a first-order reaction, since the rate must equal concentration per time. Reading order from the rate-constant units is a quick diagnostic.

84. D — At equilibrium the forward and reverse rates balance, so $K = k_{forward}/k_{reverse} = 8/2 = 4$. This links the kinetic constants to the equilibrium position.

85. B — A catalyst poison deactivates the catalyst by binding to and blocking its active sites, denying reactants access. Guard beds and purification protect catalysts from such poisons.

86. A — Selectivity is desired product over by-product, 90/30 = 3. A high selectivity reduces waste and simplifies downstream separation.

87. C — Future worth is $P(1 + i)^n = 8000 \times 1.05^6 = 8000 \times 1.3401 = \$10,721$. Compounding grows the sum forward at the stated rate.

88. A — Present worth is $F/(1 + i)^n = 15,000/1.08^4 = 15,000/1.3605 = \$11,025$. Discounting reflects that a future sum is worth less today.

89. D — Straight-line depreciation is $(120,000 - 0)/10 = \$12,000$ per year. This even allocation spreads the asset's cost across its service life.

90. C — A rate of return of 15% exceeds the 12% hurdle rate, so the project should be accepted. A project clears the screen whenever its return beats the minimum acceptable rate.

91. D — The piping and instrumentation diagram shows every instrument and control loop, serving as the master reference for the control system. Its detail exceeds that of the block flow and process flow diagrams.

92. A — A larger heat-exchanger area lowers operating cost by improving heat recovery but raises the capital cost of the larger unit. Balancing these opposing trends defines the optimum size.

93. D — Updating with the cost index gives $80,000 \times (600/400) = \$120,000$. The index ratio corrects the historical cost for inflation.

94. C — Austenitic stainless steel retains toughness at cryogenic temperatures, making it suitable for low-temperature service, whereas ordinary carbon steel and cast iron become brittle. Its face-centred-cubic structure avoids the ductile-to-brittle transition.

95. C — A positive-displacement metering pump suits low-flow, high-precision dosing, delivering a fixed volume per stroke regardless of pressure. Centrifugal pumps lack the accuracy needed for metering.

96. A — When mixing controls the process, scale-up holds power per unit volume constant to preserve comparable agitation. This keeps the mixing intensity similar across scales.

97. D — A relief valve is sized for the worst credible overpressure scenario, often external fire or a blocked outlet, since it must pass the largest possible relief load. Undersizing would leave the vessel unprotected in the governing case.

98. C — A larger time constant means the system reaches its new steady state more slowly, since it takes longer to respond to a change. The time constant directly characterises the speed of the response.

99. B — The control valve is the final control element in most loops, translating the controller's signal into a change in flow. It is the device that physically acts on the process.

100. B — Feedforward control requires measuring the disturbance variable so the controller can compensate before the disturbance affects the output. Without this measurement, only feedback correction is possible.

101. D — Excessive integral action causes the controller to overcorrect, producing oscillation and overshoot as accumulated error drives the output too far. Proper tuning balances offset removal against stability.

102. C — The autoignition temperature is the temperature at which a substance ignites spontaneously without any external spark or flame. It is distinct from, and usually higher than, the flash point.

103. C — Below the lower explosive limit the fuel–air mixture is too lean to ignite, lacking enough fuel to sustain combustion. Keeping a mixture below the LEL is a fire-prevention strategy.

104. D — The IDLH value is the concentration immediately dangerous to life and health, the level from which a worker could not escape without serious harm. It guides the selection of emergency respiratory protection.

105. D — A Class B fire involves flammable liquids and gases, requiring an extinguishing agent that smothers or interrupts combustion rather than water. Matching the extinguisher class to the fuel is essential.

106. B — Source reduction sits at the top of the waste-management hierarchy because preventing waste is more effective than treating or disposing of it later. Reducing waste at the source cuts both cost and environmental impact.

107. D — An engineer must refuse to certify work that does not meet code, since the seal attests to compliance and the public's safety depends on it. Certifying non-compliant work would breach both ethics and law.

108. D — An engineer asked to work outside their expertise should decline the work or bring in qualified assistance, consistent with practising only within their competence. Proceeding unqualified would endanger the public.

109. B — Green engineering focuses on preventing pollution at its source rather than relying on end-of-pipe treatment. Designing waste out of a process is more effective and economical than cleaning it up afterward.

110. B — An engineer holding shares in a vendor under evaluation must disclose that financial interest to the relevant parties, since it could bias their judgement. Transparency allows the conflict to be managed appropriately.