PRACTICE EXAM 8: FE CHEMICAL SIMULATION (110 QUESTIONS)

Mathematics

1. Solve the separable equation dy/dx = x/y with the initial condition y(0) = 2. Which relation describes the solution?

A. $y^2 + x^2 = 4$

B. $y = x + 2$

C. $y^2 - x^2 = 4$

D. y = 2e^x

2. What is the indefinite integral of x·e^x?

A. $x^2e^x/2 + C$

B. e^x + C

C. xe^x + C

D. $(x - 1)e^x + C$

3. What are the dimensions of the matrix product formed by multiplying a 2 × 3 matrix by a 3 × 4 matrix?

A. 2 × 4

B. 3 × 3

C. 4 × 2

D. 2 × 3

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

A. 14

B. 5

C. 10

D. 12

5. What is the dot product of the vectors (1, 2, 3) and (4, 5, 6)?

A. 14

B. 32

C. 21

D. 0

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

A. $1/x^2$

B. $2x$

C. $2/x$

D. $1/(2x^2)$

Probability and Statistics

7. Two independent events have P(A) = 0.5 and P(B) = 0.6. What is the probability that both occur?

A. 1.1

B. 0.6

C. 0.5

D. 0.30

8. What is the arithmetic mean of the data set 10, 20, 30, 40, and 50?

A. 30

B. 25

C. 150

D. 35

9. What is the median of the data set 3, 7, 9, 12, and 20?

A. 9

B. 12

C. 7

D. 10.2

10. Two mutually exclusive events have P(A) = 0.2 and P(B) = 0.3. What is the probability that A or B occurs?

A. 0.06

B. 0.5

C. 0.44

D. 0.1

11. A binomial process has 20 trials with a success probability of 0.1. What is the expected number of successes?

A. 20

B. 0.1

C. 2

D. 18

Engineering Sciences

12. A pressure of 200 kPa acts on a flat surface of area 0.5 m². What is the resulting force?

A. 400 kN

B. 100 kN

C. 0.4 kN

D. 250 kN

13. A spring with stiffness 200 N/m is compressed by 0.5 m. How much energy is stored, using ½kx²?

A. 25 J

B. 50 J

C. 100 J

D. 12.5 J

14. Three resistors of 2 Ω, 3 Ω, and 5 Ω are connected in series. What is the total resistance?

A. 0.97 Ω

B. 1 Ω

C. 30 Ω

D. 10 Ω

15. A net force of 100 N acts on a 20 kg mass. What is the acceleration?

A. 5 m/s^2

B. 2000 m/s^2

C. 0.2 m/s^2

D. 20 m/s^2

Materials Science

16. The total area under a material's stress–strain curve up to fracture represents its:

A. Stiffness

B. Toughness

C. Hardness

D. Density

17. The stress at which a material begins to deform permanently is called the:

A. Ultimate strength

B. Fracture stress

C. Yield strength

D. Proportional limit modulus

18. According to the Hall–Petch relationship, what is the effect of decreasing the grain size of a metal?

A. It decreases the strength

B. It has no effect on strength

C. It lowers the melting point

D. It increases the yield strength

19. Accelerated corrosion that occurs where two dissimilar metals are in electrical contact is called:

A. Pitting

B. Galvanic corrosion

C. Erosion

D. Fatigue cracking

20. Ceramic materials are generally characterised as being:

A. Soft and ductile with low melting points

B. Hard and brittle with high melting points

C. Electrically conductive and malleable

D. Flexible and easily reshaped

Chemistry and Biology

21. Approximately how many particles are contained in one mole of a substance?

A. 3.14×10^{23}

B. 1.0×10^{6}

C. 9.81×10^{23}

D. 6.02×10^{23}

22. A reaction produces 80 g of product against a theoretical maximum of 100 g. What is the percent yield?

A. 80%

B. 125%

C. 20%

D. 100%

23. Two moles of an ideal gas occupy 0.05 m^3 at 300 K. What is the pressure (R = 8.314 J/mol·K)?

A. 49.9 kPa

B. 200 kPa

C. 99.8 kPa

D. 8.31 kPa

24. An endothermic reaction is one that:

A. Absorbs heat from the surroundings

B. Releases heat to the surroundings

C. Has no enthalpy change

D. Always occurs spontaneously

25. How does a catalyst increase the rate of a chemical reaction?

A. By shifting the equilibrium toward products

B. By providing a lower-activation-energy pathway

C. By increasing the heat of reaction

D. By being consumed during the reaction

26. What is the molarity of a solution containing 0.25 mol of solute in 0.5 L of solution?

A. 0.125 M

B. 2 M

C. 0.25 M

D. 0.5 M

27. A covalent bond between two atoms is formed by:

A. Transferring electrons completely

B. Sharing electron pairs between atoms

C. Electrostatic attraction between ions

D. A sea of delocalised electrons

28. Glycolysis breaks down a glucose molecule to yield which principal product?

A. Carbon dioxide only

B. Lactic acid only

C. Pyruvate

D. Glucose-6-phosphate as the final product

Fluid Mechanics

29. A fluid (density 1200 kg/m³, viscosity 3×10^{-3} Pa·s) flows at 2.5 m/s through a 0.04 m pipe. What is the Reynolds number?

A. 400

B. 4000

C. 10000

D. 40000

30. A liquid of density 850 kg/m³ flows at a volumetric rate of 0.005 m³/s. What is the mass flow rate?

A. 850 kg/s

B. 4.25 kg/s

C. 170 kg/s

D. 0.0059 kg/s

31. In a horizontal pipe where the velocity decreases through an expansion, what happens to the static pressure?

A. It increases

B. It decreases

C. It stays constant

D. It drops to zero

32. What is the primary cause of head loss at a sudden pipe expansion?

A. Increased fluid density

B. Higher viscosity downstream

C. Turbulent eddies dissipating energy

D. A rise in fluid temperature only

33. A pump delivers 3 kW of hydraulic power while drawing 4 kW of shaft power. What is its efficiency?

A. 75%

B. 133%

C. 25%

D. 12%

34. A Pitot tube inserted into a flow is used to determine the:

A. Fluid velocity

B. Fluid density

C. Fluid temperature

D. Pipe roughness

35. A liquid has a density of 800 kg/m³. What is its specific gravity relative to water?

A. 800

B. 0.8

C. 1.25

D. 8

36. In fully developed laminar flow through a circular pipe, the velocity profile is:

A. Flat and uniform

B. Parabolic

C. Linear

D. Logarithmic

37. The hydrostatic force on a vertical wall holding back a liquid increases with:

A. The square of the depth

B. The inverse of the depth

C. The area only, independent of depth

D. No dependence on depth

Thermodynamics

38. A Carnot engine operates between 600 K and 450 K. What is its maximum efficiency?

A. 75%

B. 50%

C. 33%

D. 25%

39. One mole of an ideal gas is heated through 100 K at constant pressure. What expansion work is done, $W = nR\Delta T$?

A. 8.31 J

B. 831 J

C. 8314 J

D. 100 J

40. A closed system has its internal energy increased by 400 J while doing 100 J of work. How much heat was added?

A. 300 J

B. 500 J

C. 400 J

D. 100 J

41. Wet steam has a quality of 0.95, with hf = 300 kJ/kg and hfg = 2300 kJ/kg. What is its enthalpy?

A. 2300 kJ/kg

B. 2600 kJ/kg

C. 2485 kJ/kg

D. 2185 kJ/kg

42. A refrigeration cycle has a coefficient of performance of 4 for cooling. What is the heating COP of the same cycle used as a heat pump?

A. 5

B. 4

C. 3

D. 0.25

43. Applying the Gibbs phase rule, how many degrees of freedom does a two-component, two-phase system have?

A. 0

B. 1

C. 3

D. 2

44. At equilibrium, what is the value of the Gibbs free energy change of a reaction?

A. Positive

B. Zero

C. Negative

D. Infinite

45. In a vapour-compression refrigeration cycle, passing the refrigerant through the expansion valve causes it to:

A. Rise in pressure and temperature

B. Condense fully to a liquid

C. Superheat into a vapour

D. Drop in pressure and temperature

46. When two different ideal gases at the same temperature and pressure are mixed, the entropy of the system:

A. Decreases

B. Stays constant

C. Becomes negative

D. Increases

Material and Energy Balances

47. A splitter divides a single feed into two outlet streams. What is the composition of each outlet?

A. Richer in the heavy component

B. Identical to the feed

C. Pure in one component

D. Unrelated to the feed

48. A crystalliser receives 200 kg of a 25% solute solution, and 30 kg of pure solute crystallises out. How much solute remains dissolved in the mother liquor?

A. 50 kg

B. 30 kg

C. 25 kg

D. 20 kg

49. Complete combustion of one mole of methane requires 2 mol of oxygen. With air containing 21% oxygen, how many moles of air are needed?

A. 2 mol

B. 4.76 mol

C. 9.52 mol

D. 21 mol

50. A reactor is fed 500 mol/h and achieves 60% single-pass conversion, with unreacted material recycled. What is the recycle rate?

A. 200 mol/h

B. 300 mol/h

C. 500 mol/h

D. 60 mol/h

51. Absolute humidity is defined as the mass of water vapour per unit:

A. Mass of dry air

B. Total volume of gas

C. Mole of vapour

D. Mass of liquid water

52. How much heat must be removed to cool 100 kg of water from 80 °C to 30 °C, with a specific heat of 4.18 kJ/kg·K?

A. 4180 kJ

B. 8360 kJ

C. 20900 kJ

D. 12540 kJ

53. In the reaction $A \rightarrow 2B$, 5 mol of A reacts completely. How many moles of B are formed?

A. 5 mol

B. 2.5 mol

C. 10 mol

D. 15 mol

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

A. 25%

B. 33%

C. 75%

D. 20%

55. For a non-reactive process at steady state, what are the values of the generation and consumption terms in the balance?

A. Zero, so input equals output

B. Equal to the accumulation

C. Equal to the recycle rate

D. Always positive

56. Complete combustion of ethane follows $C_2H_6 + 3.5O_2 \rightarrow 2CO_2 + 3H_2O$. How many moles of carbon dioxide form from 2 mol of ethane?

A. 4 mol

B. 2 mol

C. 6 mol

D. 8 mol

57. A 1000 kg/h stream is arranged so that 40% bypasses a reactor. What is the flow rate of the bypass stream?

A. 600 kg/h

B. 400 kg/h

C. 1000 kg/h

D. 1400 kg/h

Heat Transfer

58. A 0.1 m thick wall (k = 0.8 W/m·K, area 10 m²) has a 25 °C temperature difference across it. What is the conductive heat rate?

A. 200 W

B. 800 W

C. 1000 W

D. 2000 W

59. A 2 m² surface transfers heat by convection with h = 25 W/m²·K and a temperature difference of 40 °C. What is the heat rate?

A. 500 W

B. 1000 W

C. 250 W

D. 2000 W

60. What is the approximate value of the Stefan–Boltzmann constant?

A. 9.81 $W/m^2 \cdot K^4$

B. 8.314 $W/m^2 \cdot K^4$

C. 5.67×10^{-8} $W/m^2 \cdot K^4$

D. 6.02×10^{23} $W/m^2 \cdot K^4$

61. In a counter-current exchanger, the hot stream cools from 120 °C to 80 °C while the cold stream warms from 30 °C to 70 °C. What is the log-mean temperature difference?

A. 50 °C

B. 0 °C

C. 25 °C

D. 100 °C

62. How does the thermal conductivity of a gas compare with that of a metal?

A. It is higher than that of metals

B. It is equal to that of metals

C. It is equal to that of liquids

D. It is much lower than that of metals

63. Fin efficiency is defined as the ratio of the actual heat transferred by the fin to the heat that would be transferred if:

A. Only the base conducted heat

B. The fin tip radiated all the heat

C. The entire fin were at the base temperature

D. A flat surface replaced the fin

64. A shell-and-tube exchanger with one shell pass and two tube passes requires what adjustment when applying the LMTD method?

A. No correction is needed

B. A doubling of the area

C. A zero driving force

D. An LMTD correction factor F

65. Natural convection is driven primarily by:

A. Buoyancy arising from density differences

B. An external circulating pump

C. A forced fan airflow

D. Radiation pressure

66. The lumped-capacitance method for transient conduction is valid when the Biot number is:

A. Greater than 10

B. Less than 0.1

C. Exactly 1

D. Negative

Mass Transfer and Separation

67. How does gas-phase diffusivity change as temperature increases?

A. It increases

B. It decreases

C. It stays constant

D. It drops to zero

68. If the relative volatility of a binary mixture equals 1, the components:

A. Separate very easily

B. Form a perfectly ideal solution

C. Cannot be separated by ordinary distillation

D. Both have a very high vapour pressure

69. At total reflux, the number of theoretical stages required by a distillation column is:

A. Infinite

B. At its minimum

C. Zero

D. Unchanged from minimum reflux

70. A good solvent for liquid–liquid extraction should possess:

A. Complete miscibility with the feed

B. The same density as the feed

C. A very high boiling point only

D. High selectivity and low mutual solubility with the feed

71. A dilute absorber removes 90% of a solute, so C_in/C_out = 10. What is the number of transfer units, NTU = ln(C_in/C_out)?

A. 0.9

B. 0.1

C. 9

D. 2.3

72. Flooding in a packed column occurs when:

A. The liquid rate drops to zero

B. The gas velocity is so high that liquid cannot drain downward

C. The column becomes too cold

D. The packing pieces are too large

73. A higher Henry's law constant for a gas indicates that the gas is:

A. More soluble in the liquid

B. Less soluble in the liquid

C. Equally soluble in the liquid

D. Chemically inert

74. During the constant-rate period of drying, the surface temperature of the wet solid approaches the:

A. Dry-bulb temperature

B. Boiling point

C. Dew point

D. Wet-bulb temperature

75. Reverse osmosis rejects dissolved ions primarily by means of:

A. A dense semi-permeable membrane driven by applied pressure

B. A coarse filter that screens by particle size

C. Gravity settling of the ions

D. Evaporation of the water

Solids Handling

76. What is the sphericity of a perfect sphere?

A. 0

B. 1

C. 0.5

D. Infinity

77. For very small particles settling slowly through a fluid, the drag is described by:

A. Newton's law in the turbulent regime

B. An intermediate-regime correlation

C. Stokes' law in the laminar regime

D. A condition of no drag at all

78. A filter aid such as diatomaceous earth is added to a slurry in order to:

A. Increase the cake density

B. Improve cake permeability and prevent blinding

C. Dissolve the suspended solids

D. Raise the slurry temperature

79. The chief advantage of a fluidised bed is its:

A. Consistently very low pressure drop

B. Complete absence of particle attrition

C. Plug-flow behaviour of the solids

D. Excellent mixing and uniform temperature

Chemical Reaction Engineering

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

A. 0.5 mol/L

B. 0.25 mol/L

C. 0.135 mol/L

D. 0.368 mol/L

81. A zero-order reaction has k = 1 mol/L·min and an initial concentration of 4 mol/L. What is its half-life, $t_{½} = C_0/(2k)$?

A. 4 min

B. 2 min

C. 0.69 min

D. 8 min

82. For a fixed reactor volume and positive-order kinetics, which reactor type achieves the highest conversion?

A. A single CSTR

B. A batch reactor run for a short time

C. A CSTR with a bypass

D. A plug-flow reactor

83. Activation energy is conventionally expressed in which units?

A. J/mol

B. mol/s

C. 1/s

D. K

84. In a multi-step reaction mechanism, the overall rate is governed by the:

A. Slowest step

B. Fastest step

C. First step in all cases

D. Last step in all cases

85. For an endothermic reaction, what is the effect of raising the temperature on the equilibrium constant?

A. It decreases K

B. It has no effect on K

C. It halves the reaction rate

D. It increases K

86. In heterogeneous catalysis, the step that immediately follows the arrival of reactants at the catalyst surface is:

A. Desorption of the products

B. Bulk diffusion away from the surface

C. Adsorption onto the active sites

D. Condensation within the pores

Engineering Economics

87. What is the future worth of $5,000 invested for 10 years at 8% interest ($1.08^{10} = 2.1589$)?

A. $5,400

B. $9,000

C. $5,000

D. $10,795

88. A vessel costs $250,000 at a capacity of 10 m^3. Using the six-tenths rule, estimate the cost of a 40 m^3 vessel.

A. $1,000,000

B. $250,000

C. $431,000

D. $574,000

89. A project requires $800,000 of capital and returns $200,000 per year. What is the simple payback period?

A. 2 yr

B. 4 yr

C. 6 yr

D. 8 yr

90. A project returns $3,000 at the end of each year for 5 years at 10% interest (P/A factor 3.7908). What is its present worth?

A. $15,000

B. $3,000

C. $9,000

D. $11,372

Process Design

91. The economic optimum of a process design generally occurs at the point where:

A. The capital cost alone is lowest

B. The operating cost alone is lowest

C. The total cost is minimised

D. The equipment size is largest

92. In a typical process plant, steam is most commonly used as a:

A. Coolant

B. Reactant catalyst

C. Heating medium

D. Lubricant

93. The "N + 1" sparing philosophy for equipment means installing:

A. Exactly the number of units needed

B. One more unit than required

C. Twice the required number of units

D. No spare units at all

94. Which process diagram is normally used to develop the material and energy balance of a plant?

A. The block flow diagram

B. The P&ID

C. The process flow diagram

D. The plot plan

95. Geometric similarity in equipment scale-up means holding constant the:

A. Absolute physical dimensions

B. Impeller rotational speed

C. Ratios of all linear dimensions

D. Total power input

96. For service at very high temperatures, a suitable material of construction is:

A. A nickel-based superalloy

B. PVC plastic

C. Ordinary aluminium

D. Mild steel

97. For transferring a highly viscous fluid, which pump type is preferred?

A. A positive-displacement pump

B. A centrifugal pump only

C. A jet pump

D. An axial-flow pump

Process Control

98. A proportional-only controller, after a sustained load change, leaves the process with a:

A. Complete absence of offset

B. Continuously growing oscillation

C. Steady-state offset

D. Infinite controller gain

99. A thermocouple measures temperature by generating:

A. A resistance change with temperature

B. A voltage from the temperature difference between its junctions

C. A pressure change with temperature

D. A visible colour change

100. A fail-closed control valve on a fuel line moves to which position when its signal is lost?

A. Fully open

B. Half open

C. Fully closed

D. Its last held position

101. Ratio control is used to maintain a:

A. Constant single flow rate

B. Constant temperature

C. Fixed ratio between two flow streams

D. Constant tank level

Safety, Health, and Environment

102. The flash point of a liquid is the lowest temperature at which it:

A. Gives off enough vapour to form an ignitable mixture in air

B. Boils completely

C. Freezes solid

D. Reaches its critical point

103. A risk matrix ranks hazards by combining which two factors?

A. Cost and schedule

B. Temperature and pressure

C. Likelihood and severity

D. Flow rate and level

104. What is the first required action before entering a confined space?

A. Begin the work immediately

B. Test the atmosphere for oxygen and contaminants

C. Remove all ventilation equipment

D. Seal the entry point behind you

105. The most common route of industrial chemical exposure for workers is:

A. Ingestion

B. Injection

C. Inhalation

D. Radiation

106. A containment dike (bund) built around a storage tank is designed to:

A. Support the weight of the tank

B. Insulate the stored contents

C. Cool the stored liquid

D. Contain a spill and prevent it from spreading

Ethics and Professional Practice

107. When a design decision pits cost savings against public safety, the engineer must:

A. Prioritise public safety over cost savings

B. Always choose the cheaper option

C. Defer the decision entirely to management

D. Ignore the safety concern if it seems minor

108. An engineer who discovers an error in their own already-published report should:

A. Correct it and inform the affected parties

B. Conceal it to protect their reputation

C. Shift the blame to a colleague

D. Wait for someone else to notice it

109. When an engineer substantially relies on a colleague's work, professional ethics require that they:

A. Claim the work as their own

B. Give appropriate credit to the colleague

C. Remove the colleague's name from records

D. Publish it without any attribution

110. Offering a payment to a public official to secure a contract is:

A. An acceptable business practice

B. Permissible provided it is disclosed

C. Bribery and strictly prohibited

D. Required in certain markets

Practice Exam 8 — Answer Key and Explanations

1. C — Separating gives y dy = x dx, which integrates to $y^2/2 = x^2/2 + C$; applying y(0) = 2 yields C = 2, so $y^2 - x^2 = 4$. Separable equations of this form are the simplest analytic route through first-order dynamics.

2. D — Integration by parts with u = x and dv = e^x dx gives xe^x − ∫e^x dx = (x − 1)e^x + C. By-parts handles products of a polynomial and an exponential, common in transform and moment integrals.

3. A — Multiplying an m × n matrix by an n × p matrix gives an m × p result, so 2 × 3 times 3 × 4 yields 2 × 4. The inner dimensions must match and the outer dimensions define the product.

4. C — A 2 × 2 determinant is ad − bc = (3)(4) − (2)(1) = 12 − 2 = 10. The determinant indicates invertibility and scales areas under the linear transformation.

5. B — The dot product is 1×4 + 2×5 + 3×6 = 4 + 10 + 18 = 32. This scalar measures projection and appears in work and flux calculations.

6. C — Using the chain rule, $d/dx \ln(x^2) = (1/x^2)(2x) = 2/x$. Recognising the simplification avoids errors in logarithmic differentiation.

7. D — For independent events, P(A and B) = P(A)·P(B) = 0.5 × 0.6 = 0.30. Multiplying probabilities applies only when events do not influence one another.

8. A — The mean is the sum divided by the count, (10 + 20 + 30 + 40 + 50)/5 = 150/5 = 30. The mean is the balance point of the data, sensitive to every value.

9. A — With the five values already ordered, the median is the middle one, 9. The median resists the influence of extreme values better than the mean.

10. B — For mutually exclusive events, P(A or B) = P(A) + P(B) = 0.2 + 0.3 = 0.5, with no overlap to subtract. Disjoint events cannot occur together, so their probabilities simply add.

11. C — The mean of a binomial distribution is np = 20 × 0.1 = 2. This expected count guides quality-sampling and reliability estimates.

12. B — Force is pressure times area, 200,000 × 0.5 = 100,000 N = 100 kN. This product sizes the loads on vessel walls, pistons, and closures.

13. A — Spring energy is $\frac{1}{2}kx^2 = \frac{1}{2} \times 200 \times 0.5^2 = \frac{1}{2} \times 200 \times 0.25 = 25$ J. The square dependence on displacement means energy rises sharply with compression.

14. D — Series resistances add directly, 2 + 3 + 5 = 10 Ω. The total in series always exceeds any single resistor, the opposite of the parallel case.

15. A — Newton's second law gives $a = F/m = 100/20 = 5$ m/s². Acceleration is proportional to net force and inversely to mass.

16. B — The area under the full stress–strain curve measures toughness, the total energy a material absorbs before fracture. A tough material combines strength with ductility, resisting sudden failure.

17. C — The yield strength is the stress at which permanent (plastic) deformation begins, beyond the elastic region. Designing below yield keeps a component within its recoverable elastic range.

18. D — The Hall–Petch relationship shows that smaller grains raise yield strength, because grain boundaries impede dislocation motion. Grain refinement is a key way to strengthen metals without changing composition.

19. B — Galvanic corrosion occurs where two dissimilar metals are in electrical contact in an electrolyte, the more active metal corroding preferentially. Avoiding such couples, or insulating them, prevents this accelerated attack.

20. B — Ceramics are typically hard and brittle with high melting points, owing to their strong ionic and covalent bonding. These traits make them excellent for refractory and wear-resistant uses but poor where impact toughness is needed.

21. D — One mole contains Avogadro's number of particles, about 6.02×10^{23}. This constant links the molecular scale to measurable masses and volumes.

22. A — Percent yield is actual over theoretical, 80/100 = 80%. It quantifies losses to side reactions and incomplete conversion in a real process.

23. C — From PV = nRT, P = nRT/V = (2 × 8.314 × 300)/0.05 = 99,768 Pa ≈ 99.8 kPa. Consistent SI units give the pressure directly in pascals.

24. A — An endothermic reaction absorbs heat from its surroundings, so its enthalpy change is positive. Such reactions require a continuous heat supply to proceed.

25. B — A catalyst speeds a reaction by offering a pathway of lower activation energy, without being consumed or shifting the equilibrium. More molecules can then react at a given temperature.

26. D — Molarity is moles over litres, 0.25/0.5 = 0.5 M. This concentration measure underlies dilution and reaction-stoichiometry calculations in solution.

27. B — A covalent bond forms when atoms share one or more pairs of electrons, in contrast to the electron transfer of ionic bonding. Shared pairs hold the atoms together in molecules.

28. C — Glycolysis converts one glucose molecule into two molecules of pyruvate, releasing a small amount of energy. Pyruvate then feeds into aerobic or anaerobic pathways for further energy extraction.

29. D — Reynolds number is $\rho v D/\mu$ = (1200 × 2.5 × 0.04)/0.003 = 40,000. This turbulent value dictates the friction correlation that applies.

30. B — Mass flow rate is density times volumetric flow, 850 × 0.005 = 4.25 kg/s. This conversion links volumetric and mass-based balances.

31. A — By Bernoulli's principle, where the velocity decreases in a horizontal pipe the static pressure rises, conserving total head. This pressure recovery occurs in diffusers and expansions.

32. C — A sudden expansion generates turbulent eddies that dissipate kinetic energy, producing the head loss. Smoothly tapered transitions reduce this loss by suppressing the eddies.

33. A — Pump efficiency is hydraulic power over shaft power, 3/4 = 75%. The shortfall represents losses to friction and internal recirculation within the pump.

34. A — A Pitot tube determines fluid velocity by measuring the stagnation pressure and relating it to the dynamic pressure $\frac{1}{2}\rho v^2$. It is a standard device for airspeed and flow-velocity measurement.

35. B — Specific gravity is the ratio of a substance's density to water's, 800/1000 = 0.8. A value below one means the liquid is lighter than water and will float on it.

36. B — Fully developed laminar pipe flow has a parabolic velocity profile, zero at the wall and maximum at the centre. This profile gives the average velocity as half the maximum.

37. A — Hydrostatic force on a vertical surface rises with the square of depth, since both the pressure and the submerged area increase with depth. This drives the thicker walls required at the base of tall tanks.

38. D — Carnot efficiency is $1 - T_c/T_h = 1 - 450/600 = 0.25$, or 25%. The small temperature ratio limits how much heat can be converted to work.

39. B — Constant-pressure expansion work is $nR\Delta T = 1 \times 8.314 \times 100 = 831$ J. This is the work an ideal gas does pushing back its surroundings as it warms.

40. B — The first law gives $Q = \Delta U + W = 400 + 100 = 500$ J. Heat supplied both raises internal energy and provides the work done by the system.

41. C — Enthalpy of wet steam is $h_f + x \cdot h_{fg} = 300 + 0.95 \times 2300 = 2485$ kJ/kg. Quality weights the latent-heat term to give the two-phase enthalpy.

42. A — The heating COP exceeds the cooling COP by exactly one, so $4 + 1 = 5$, because the heat pump delivers both the absorbed heat and the work input. This identity follows directly from the energy balance on the cycle.

43. D — The Gibbs phase rule gives $F = C - P + 2 = 2 - 2 + 2 = 2$ for a binary two-phase system. Two degrees of freedom mean two intensive variables, such as temperature and composition, can be set independently.

44. B — At equilibrium the Gibbs free energy change is zero, marking the balance between forward and reverse tendencies. Departures from zero indicate a driving force toward products or reactants.

45. D — The expansion valve throttles the refrigerant, dropping both its pressure and temperature so it can absorb heat in the evaporator. This pressure let-down is essential to the refrigeration cycle.

46. D — Mixing two different ideal gases increases entropy, since the molecules spread into a larger accessible volume. This entropy of mixing is spontaneous and irreversible.

47. B — A splitter merely divides a stream, so each outlet has the same composition as the feed, differing only in flow rate. This contrasts with a separator, which changes composition.

48. D — The feed contains $0.25 \times 200 = 50$ kg of solute; with 30 kg crystallising as pure solid, $50 - 30 = 20$ kg remains dissolved in the mother liquor. A solute balance closes the crystalliser calculation.

49. C — Two moles of oxygen are needed, and since air is 21% oxygen, the air required is $2/0.21 = 9.52$ mol. Converting an oxygen demand to an air supply is routine in combustion balances.

50. A — At 60% single-pass conversion, 40% of the 500 mol/h feed is unreacted, giving $0.40 \times 500 = 200$ mol/h returned to the reactor. Recycling this unreacted material raises overall utilisation.

51. A — Absolute humidity is the mass of water vapour carried per unit mass of dry air. Using the unchanging dry-air mass as the basis simplifies humidification and drying balances.

52. C — Heat removed is $mC_p\Delta T = 100 \times 4.18 \times 50 = 20{,}900$ kJ. This sensible-heat relation sizes the cooler for a non-phase-change temperature drop.

53. C — The stoichiometry produces two moles of B per mole of A, so 5 mol of A yields 10 mol of B. Reaction stoichiometry converts reactant consumed into product formed.

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

55. A — In a non-reactive steady process, generation and consumption are zero, so the balance reduces to input equals output. With no reaction and no accumulation, mass simply passes through.

56. A — Each mole of ethane yields two moles of CO_2, so 2 mol of ethane produces 4 mol. Combustion stoichiometry fixes the carbon dioxide output.

57. B — The bypass fraction is 0.40, so the bypass stream is 0.40 × 1000 = 400 kg/h. Bypassing part of a stream lets a designer blend treated and untreated material to a target.

58. D — Fourier's law gives $Q = kA\Delta T/L = (0.8 \times 10 \times 25)/0.1 = 2000$ W. The large area and thin wall pass a substantial heat rate.

59. D — Convective heat rate is $hA\Delta T = 25 \times 2 \times 40 = 2000$ W. The coefficient h reflects how vigorously the fluid carries heat from the surface.

60. C — The Stefan–Boltzmann constant is approximately 5.67×10^{-8} W/m²·K⁴, relating a black body's emissive power to the fourth power of its temperature. It is fundamental to all radiation calculations.

61. A — Both terminal differences are 120 − 70 = 50 °C and 80 − 30 = 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. D — Gases conduct heat far more poorly than metals, by several orders of magnitude, because their molecules are widely spaced. This is why trapped gas in porous insulation is so effective at limiting conduction.

63. C — Fin efficiency compares the actual heat the fin transfers to the heat it would transfer if the entire fin sat at the base temperature. A value near one means the fin material conducts heat efficiently to its tip.

64. D — A one-shell, two-tube-pass exchanger is not purely counter-current, so its true driving force is the LMTD multiplied by a correction factor F (less than one). This factor accounts for the mixed flow directions.

65. A — Natural convection is driven by buoyancy arising from density differences that temperature gradients create, with no external pump or fan. Warmer, lighter fluid rises and cooler fluid sinks, setting up circulation.

66. B — The lumped-capacitance method applies when the Biot number is below about 0.1, indicating that internal conduction is fast compared with surface convection. The body's temperature can then be treated as uniform during transient heating or cooling.

67. A — Gas-phase diffusivity increases with temperature, as faster molecular motion accelerates diffusion. This temperature dependence enhances mass transfer in heated gas systems.

68. C — A relative volatility of one means the components have identical volatility, so no enrichment occurs and ordinary distillation cannot separate them. This condition signals an azeotrope or the need for an alternative method.

69. B — At total reflux the operating line coincides with the diagonal, giving the maximum separation per stage and therefore the minimum number of stages. This Fenske limit bounds the shortest possible column.

70. D — A good extraction solvent has high selectivity for the solute and low mutual solubility with the feed, so the two phases separate cleanly. These properties maximise recovery while keeping the phases distinct.

71. D — For a dilute absorber, NTU = ln(C_in/C_out) = ln(10) ≈ 2.3. The number of transfer units rises with the fractional removal demanded.

72. B — Flooding occurs when the rising gas velocity is high enough to prevent the liquid from draining down through the packing, causing liquid to accumulate. It sets the upper capacity limit of a packed column.

73. B — A higher Henry's law constant means a gas is less soluble, since solubility is inversely related to the constant. This guides solvent selection for absorption.

74. D — During constant-rate drying, evaporative cooling balances heat input and the wet surface sits near the wet-bulb temperature. This period removes free surface moisture before internal diffusion becomes limiting.

75. A — Reverse osmosis rejects dissolved ions by forcing water through a dense, semi-permeable membrane under pressure that exceeds the osmotic pressure. The membrane's tight structure, not a size screen, achieves the separation.

76. B — A perfect sphere has a sphericity of exactly 1, the maximum value, since sphericity compares a particle's surface area to that of an equal-volume sphere. Irregular particles have sphericity below one.

77. C — Very small, slowly settling particles follow Stokes' law in the laminar regime, where drag is proportional to velocity. This regime underlies sedimentation and gravity classification.

78. B — A filter aid such as diatomaceous earth keeps the cake porous and prevents fine particles from blinding the medium, maintaining filtration rate. It is precoated or added to slurries that would otherwise filter poorly.

79. D — The fluidised bed's chief advantage is its excellent gas–solid mixing, which gives nearly uniform temperature throughout. This uniformity is prized in catalytic and combustion reactors.

80. D — First-order decay gives $C = C_0 e^{(-kt)} = 1 \times e^{(-0.5 \times 2)} = e^{(-1)} = 0.368$ mol/L. The concentration falls exponentially with time at a rate set by k.

81. B — For a zero-order reaction the half-life is $C_0/(2k) = 4/(2 \times 1) = 2$ min. Unlike first order, this half-life depends on the starting concentration.

82. D — For a fixed volume and positive-order kinetics, the plug-flow reactor achieves the highest conversion because it maintains a higher average concentration than a back-mixed CSTR. This makes the PFR the efficient choice for such reactions.

83. A — Activation energy is an energy per mole of reacting substance, expressed in J/mol or kJ/mol. These units make the Arrhenius exponent E_a/RT dimensionless.

84. A — In a multi-step mechanism the slowest elementary step is rate-determining and governs the overall rate. Speeding any faster step has little effect until the bottleneck is relieved.

85. D — For an endothermic reaction, heat acts as a reactant, so raising temperature shifts equilibrium toward products and increases the equilibrium constant K. This is the opposite of the exothermic case.

86. C — After reactants diffuse to the catalyst, the next step is adsorption onto the active sites, where the surface reaction then occurs. The full sequence is diffusion, adsorption, reaction, desorption, and diffusion away.

87. D — Future worth is $P(1 + i)^n = 5000 \times 1.08^{10} = 5000 \times 2.1589 = \$10{,}795$. Compounding nearly doubles the sum over ten years at 8%.

88. D — The six-tenths rule gives $250{,}000 \times (40/10)^{0.6} = 250{,}000 \times 2.297 = \$574{,}000$. Quadrupling capacity raises cost only about 2.3-fold, reflecting the economy of scale.

89. B — Simple payback is capital over annual return, 800,000/200,000 = 4 years. The measure is quick but ignores the time value of money.

90. D — Present worth of the annuity is $3000 \times 3.7908 = \$11{,}372$. The annuity factor sums the discounted value of all five annual payments.

91. C — The economic optimum of a design lies where the total cost is minimised, balancing capital cost against operating cost as one rises and the other falls. Neither cost alone defines the best design.

92. C — Steam is the most common heating medium in process plants, valued for its high latent heat and easy distribution. It delivers heat at a controllable temperature set by its pressure.

93. B — The N + 1 sparing philosophy installs one more unit than the process requires, so operation continues if a single unit is down. This redundancy protects availability without excessive cost.

94. C — The process flow diagram, with its stream table of flows, compositions, and conditions, is used to develop the material and energy balance. It carries more detail than the block flow diagram but less than the P&ID.

95. C — Geometric similarity in scale-up holds the ratios of all linear dimensions constant, so the larger unit is a faithfully proportioned version of the smaller. Preserving these ratios is the first requirement of reliable scale-up.

96. A — Nickel-based superalloys retain strength and corrosion resistance at very high temperatures, suiting them to furnace and turbine service. Common metals and plastics would soften or fail under such conditions.

97. A — A positive-displacement pump is preferred for highly viscous fluids, since it moves a fixed volume per stroke regardless of viscosity. Centrifugal pumps lose effectiveness as viscosity rises.

98. C — A proportional-only controller leaves a steady-state offset, because some error must persist to generate the corrective output. Adding integral action is what removes this residual offset.

99. B — A thermocouple generates a small voltage from the temperature difference between its measuring and reference junctions, the Seebeck effect. This voltage is then converted to a temperature reading.

100. C — A fail-closed valve moves fully closed on loss of signal, the safe state for a fuel line because it stops the flow. Choosing the fail position to drive the process to safety is a core control-design principle.

101. C — Ratio control maintains a fixed proportion between two flow streams, such as fuel and air to a burner. It adjusts one flow automatically as the other varies to hold the set ratio.

102. A — The flash point is the lowest temperature at which a liquid releases enough vapour to form an ignitable mixture in air. It is a primary indicator of a liquid's fire hazard during storage and handling.

103. C — A risk matrix ranks hazards by combining their likelihood with the severity of their consequences. Plotting these two dimensions prioritises which risks demand the strongest controls.

104. B — Before entering a confined space, the atmosphere must first be tested for adequate oxygen and the absence of toxic or flammable gases. This check guards against the asphyxiation and ignition that make confined spaces so dangerous.

105. C — Inhalation is the most common route of industrial chemical exposure, since airborne vapours, dusts, and mists are readily breathed in. This is why ventilation and respiratory protection are central to industrial hygiene.

106. D — A containment dike around a storage tank is designed to contain a spill and prevent it from spreading to the surroundings. It limits the consequences of a tank rupture or overfill.

107. A — When cost savings conflict with public safety, the engineer must prioritise safety, consistent with the paramount duty in every code of ethics. Cost cannot justify endangering the public.

108. A — An engineer who finds an error in their own published work must correct it and inform those affected, upholding honesty and protecting users of the work. Concealing the error would compound the breach.

109. B — Using a colleague's work substantially requires giving them appropriate credit, recognising their contribution honestly. Claiming others' work as one's own violates professional integrity.

110. C — Offering a payment to a public official to secure a contract is bribery and is strictly prohibited under engineering codes and the law. Such conduct corrupts fair dealing and carries severe professional and legal consequences.