PRACTICE EXAM 11: FE CHEMICAL SIMULATION (110 QUESTIONS)

Mathematics

1. The solution to the differential equation dy/dx = 3y takes which form?

A. y = 3x + C

B. y = Ce^(3x)

C. y = C·ln(3x)

D. $y = Cx^3$

2. Evaluate the definite integral of e^x from x = 0 to x = 2 ($e^2 \approx 7.39$).

A. e^2

B. $e^2 + 1$

C. 1

D. 6.39

3. Multiplying the identity matrix by any compatible matrix A produces:

A. A

B. The zero matrix

C. The transpose of A

D. The inverse of A

4. What is the derivative of x^3 with respect to x?

A. x^2

B. $3x$

C. $3x^2$

D. $x^4/4$

5. Evaluate the limit of $(1 - \cos x)/x^2$ as x approaches 0.

A. 0

B. 1/2

C. 1

D. Infinity

6. The cross product of two parallel vectors is:

A. Their sum

B. The zero vector

C. A unit vector

D. Equal to their dot product

Probability and Statistics

7. Two independent events have probabilities 0.4 and 0.25. What is the probability that both occur?

A. 0.10

B. 0.65

C. 0.4

D. 0.025

8. What is the mean of the data set 5, 10, and 15?

A. 5

B. 15

C. 10

D. 30

9. In how many ways can 2 items be chosen from 8 distinct items, where order does not matter?

A. 16

B. 56

C. 64

D. 28

10. What is the effect on the standard deviation when the same constant is added to every value in a data set?

A. It leaves the standard deviation unchanged

B. It doubles the standard deviation

C. It increases it by the constant

D. It reduces it to zero

11. Defects follow a Poisson distribution with a mean of 2. What is the probability of exactly one defect ($e^{-2} = 0.135$)?

A. 0.135

B. 0.018

C. 0.50

D. 0.271

Engineering Sciences

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

A. 20 J

B. 40 J

C. 200 J

D. 80 J

13. Three resistors of 5 Ω, 10 Ω, and 15 Ω are connected in series. What is the total resistance?

A. 2.7 Ω

B. 30 Ω

C. 10 Ω

D. 150 Ω

14. A net force accelerates a 5 kg mass at 4 m/s^2. What is the magnitude of the force?

A. 1.25 N

B. 20 N

C. 9 N

D. 0.8 N

15. A current of 3 A flows through a 4 Ω resistor. What power is dissipated?

A. 12 W

B. 144 W

C. 7 W

D. 36 W

Materials Science

16. Elastic deformation of a material is:

A. Fully recoverable when the load is removed

B. Permanent and unrecoverable

C. Always immediately preceded by fracture

D. Independent of the applied stress

17. Brittle materials characteristically fail with:

A. Extensive necking

B. Large overall elongation

C. Little plastic deformation

D. Gradual, prolonged yielding

18. Tempering of hardened steel is carried out chiefly to:

A. Increase its hardness further

B. Dissolve all of the carbon

C. Reduce brittleness and increase toughness

D. Melt the surface layer

19. Stress-corrosion cracking requires the simultaneous presence of:

A. Compression and dry air

B. Tensile stress and a corrosive environment

C. High temperature alone

D. Cyclic loading by itself

20. The glass-transition temperature of a polymer is the temperature at which it:

A. Melts completely

B. Decomposes chemically

C. Crystallises fully

D. Changes from rigid to rubbery

Chemistry and Biology

21. Which of the following is a strong base that dissociates completely in water?

A. Sodium hydroxide

B. Ammonia

C. Acetic acid

D. Water

22. What is the molar mass of carbon dioxide, CO_2?

A. 28 g/mol

B. 32 g/mol

C. 44 g/mol

D. 16 g/mol

23. A fixed quantity of gas occupies 3 L at 300 K and constant pressure. What volume does it occupy at 600 K?

A. 1.5 L

B. 3 L

C. 6 L

D. 12 L

24. Increasing the concentration of a reactant generally:

A. Increases the reaction rate

B. Decreases the reaction rate

C. Has no effect on the rate

D. Stops the reaction

25. For $2H_2 + O_2 \rightarrow 2H_2O$ with excess oxygen, how many moles of water form from 6 mol of hydrogen?

A. 3 mol

B. 12 mol

C. 6 mol

D. 2 mol

26. A solution has a hydroxide ion concentration of 1×10^{-2} mol/L. What is its pH at 25 °C?

A. 2

B. 12

C. 7

D. 14

27. A heterogeneous catalyst is characterised by being:

A. In the same phase as the reactants

B. Always a liquid

C. Consumed during the reaction

D. In a different phase from the reactants

28. Proteins are biological polymers built from repeating units of:

A. Nucleotides

B. Fatty acids

C. Monosaccharides

D. Amino acids

Fluid Mechanics

29. A fluid (density 900 kg/m^3, viscosity 0.015 Pa·s) flows at 2 m/s through a 0.05 m pipe. What is the Reynolds number?

A. 600

B. 6000

C. 60000

D. 1500

30. Incompressible flow passes into a section of one-quarter the area. If the upstream velocity is 2 m/s, what is the downstream velocity?

A. 0.5 m/s

B. 2 m/s

C. 4 m/s

D. 8 m/s

31. At a point of higher velocity in a horizontal pipe, the static pressure is:

A. Higher

B. Unchanged

C. Zero

D. Lower

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

A. 29.4 kPa

B. 3 kPa

C. 294 kPa

D. 2.94 kPa

33. For laminar pipe flow at a Reynolds number of 400, what is the Darcy friction factor?

A. 0.016

B. 0.16

C. 1.6

D. 64

34. A pump delivers 0.04 m^3/s of water against a head of 12 m. What is the ideal hydraulic power?

A. 4.71 kW

B. 0.47 kW

C. 47 kW

D. 471 W

35. A fluid flows at 3 m/s through a duct of cross-sectional area 0.2 m^2. What is the volumetric flow rate?

A. 0.067 m^3/s

B. 6 m^3/s

C. 0.6 m^3/s

D. 60 m^3/s

36. Dynamic viscosity has which SI units?

A. Pa·s

B. m^2/s

C. N/m

D. kg/m^3

37. The Reynolds number physically represents the ratio of:

A. Inertial to viscous forces

B. Pressure to velocity

C. Gravity to drag

D. Heat to mass transfer

Thermodynamics

38. A Carnot engine operates between 1000 K and 400 K. What is its maximum efficiency?

A. 40%

B. 50%

C. 60%

D. 75%

39. Four moles of an ideal gas (C_v = 20 J/mol·K) are heated by 30 K at constant volume. What is the change in internal energy?

A. 600 J

B. 1200 J

C. 2400 J

D. 240 J

40. A closed system absorbs 1000 J of heat while doing 600 J of work. What is the change in internal energy?

A. 400 J

B. 1600 J

C. −400 J

D. 1000 J

41. Steam enters an adiabatic turbine at 3100 kJ/kg and leaves at 2700 kJ/kg, flowing at 5 kg/s. What is the shaft power?

A. 1000 kW

B. 2000 kW

C. 2500 kW

D. 500 kW

42. A refrigerator removes 500 W from the cold space while consuming 200 W of work. What is its coefficient of performance?

A. 2.5

B. 3.5

C. 0.4

D. 1.4

43. An equimolar liquid mixture of A (pure vapour pressure 80 kPa) and B (40 kPa) follows Raoult's law. What is the bubble-point pressure?

A. 40 kPa

B. 80 kPa

C. 120 kPa

D. 60 kPa

44. Entropy is fundamentally a measure of:

A. The energy content of a system

B. The temperature of a system

C. The pressure of a system

D. The molecular disorder of a system

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

A. Adiabatic

B. Isobaric

C. Isothermal

D. Isochoric

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

A. Positive

B. Negative

C. Zero

D. Always equal to its Gibbs free energy change

Material and Energy Balances

47. A 600 kg/h feed enters a separator that produces a 250 kg/h overhead stream. What is the bottoms flow rate?

A. 600 kg/h

B. 250 kg/h

C. 350 kg/h

D. 850 kg/h

48. An evaporator concentrates 1000 kg/h of a 12% solids feed to a 30% solids product. What is the product flow rate?

A. 600 kg/h

B. 120 kg/h

C. 400 kg/h

D. 880 kg/h

49. Complete combustion of methane requires 2 mol of oxygen per mole. How many moles of oxygen are needed for 4 mol of methane?

A. 8 mol

B. 4 mol

C. 2 mol

D. 16 mol

50. A 150 kg stream of 20% salt is mixed with a 150 kg stream of 60% salt. What is the salt content of the mixture?

A. 20%

B. 60%

C. 40%

D. 80%

51. A reactor is fed 500 mol of A, of which 125 mol leaves unreacted. What is the conversion?

A. 25%

B. 75%

C. 100%

D. 125 mol

52. A process recycles 400 mol/h and receives a fresh feed of 200 mol/h. What is the recycle ratio?

A. 0.5

B. 2

C. 600

D. 3

53. How much heat is required to raise 30 kg of a fluid (C_p = 2 kJ/kg·K) by 25 °C?

A. 1500 kJ

B. 750 kJ

C. 3000 kJ

D. 150 kJ

54. A solid has a moisture content of 50% on a wet basis. What is the equivalent moisture content on a dry basis?

A. 50%

B. 33%

C. 200%

D. 100%

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

A. 3 mol

B. 7 mol

C. 12 mol

D. 4 mol

56. A burner needs 8 mol of oxygen stoichiometrically but is supplied with 10 mol. What is the percentage excess oxygen?

A. 20%

B. 80%

C. 125%

D. 25%

57. What is the first step in systematically solving a material balance problem?

A. Assume steady state in all cases

B. Choose a calculation basis

C. Ignore the inert components

D. Solve the energy balance first

Heat Transfer

58. A 0.1 m thick wall (k = 3 W/m·K, area 2 m^2) has a 50 °C temperature difference across it. What is the conductive heat rate?

A. 300 W

B. 600 W

C. 3000 W

D. 1500 W

59. A 2 m^2 surface transfers heat by convection with h = 60 W/m^2·K and a temperature difference of 30 °C. What is the heat rate?

A. 900 W

B. 1800 W

C. 1200 W

D. 3600 W

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

A. 4×

B. 16×

C. 8×

D. 2×

61. In a counter-current exchanger, the hot stream cools from 100 °C to 70 °C while the cold stream warms from 30 °C to 50 °C. What is the log-mean temperature difference?

A. 45 °C

B. 50 °C

C. 40 °C

D. 44.8 °C

62. Two wall layers have thermal resistances of 0.3 K/W and 0.4 K/W in series. What is the total resistance?

A. 0.7 K/W

B. 0.12 K/W

C. 0.17 K/W

D. 1.2 K/W

63. Two convective films, each 100 $W/m^2 \cdot K$, act in series with negligible wall resistance. What is the overall coefficient U?

A. 200 $W/m^2 \cdot K$

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

C. 50 $W/m^2 \cdot K$

D. 25 $W/m^2 \cdot K$

64. An exchanger has U = 250 $W/m^2 \cdot K$, area 4 m^2, and a log-mean temperature difference of 20 °C. What is the heat duty?

A. 20 kW

B. 40 kW

C. 10 kW

D. 5 kW

65. In a perfect vacuum, heat can be transferred only by:

A. Conduction

B. Radiation

C. Convection

D. All three modes

66. Which of the following conducts heat most readily?

A. Wood

B. Silver

C. Plastic

D. Air

Mass Transfer and Separation

67. A species diffuses through a 1 mm film with $D = 1.5 \times 10^{-9}$ m^2/s and a concentration difference of 20 mol/m^3. What is the molar flux?

A. 1.5×10^{-5} $mol/m^2 \cdot s$

B. 3×10^{-8} $mol/m^2 \cdot s$

C. 3×10^{-5} $mol/m^2 \cdot s$

D. 3×10^{-3} $mol/m^2 \cdot s$

68. The vapour–liquid equilibrium K-value of a component is defined as:

A. y/x

B. x/y

C. y·x

D. y + x

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

A. 1

B. 0

C. 0.5

D. Greater than 1

70. A solute with a distribution coefficient of 4 is contacted once with an equal volume of solvent. What fraction transfers to the extract?

A. 0.50

B. 0.25

C. 0.67

D. 0.80

71. A dilute absorber removes 86.5% of a solute, so C_in/C_out = 7.4. What is the number of transfer units, NTU = ln(C_in/C_out)?

A. 0.87

B. 7.4

C. 2.0

D. 0.5

72. The capacity of a liquid solvent to absorb a gas generally rises with:

A. Increasing pressure

B. Increasing temperature

C. Decreasing solvent flow

D. Decreasing pressure

73. The energy input to a reverse-osmosis unit is used chiefly to:

A. Heat the feed stream

B. Cool the permeate

C. Generate an electric field

D. Pressurise the feed above its osmotic pressure

74. Murphree efficiency is a measure defined for:

A. The whole column

B. The condenser

C. The reboiler

D. An individual tray

75. In the two-film theory, the controlling resistance is the film with the:

A. Lower mass-transfer coefficient

B. Higher mass-transfer coefficient

C. Larger diffusivity

D. Smaller concentration

Solids Handling

76. A 100 μm particle ($\Delta\rho$ = 2500 kg/m³) settles in a fluid of viscosity 1×10^{-3} Pa·s. What is its Stokes' law terminal velocity?

A. 6.8×10^{-3} m/s

B. 1.36×10^{-2} m/s

C. 2.7×10^{-2} m/s

D. 5.4×10^{-3} m/s

77. A finer screen, designated by a higher mesh number, has:

A. Larger openings

B. More wires removed

C. The same openings

D. Smaller openings

78. Cake filtration is driven primarily by the:

A. Temperature gradient

B. Pressure difference across the medium

C. Concentration gradient

D. Applied electric field

79. The bulk density of a powder accounts for:

A. Only the solid material

B. Only any liquid present

C. The solid plus the inter-particle voids

D. The gas phase alone

Chemical Reaction Engineering

80. A first-order reaction ($k = 0.2\ \text{min}^{-1}$) starts at 5 mol/L. What is the concentration after 5 minutes, using $C = C_0e\text{^}(-kt)$?

A. 2.5 mol/L

B. 1.84 mol/L

C. 0.92 mol/L

D. 3.0 mol/L

81. A first-order reaction ($k = 0.5\ min^{-1}$) reaches 50% conversion in a CSTR. What space time is required?

A. 2 min

B. 4 min

C. 1 min

D. 0.5 min

82. A first-order reaction has a rate constant of $0.0462\ min^{-1}$. What is its half-life?

A. 30 min

B. 15 min

C. 7.5 min

D. 60 min

83. A reaction rate increases eightfold when the reactant concentration is doubled. What is the reaction order?

A. 1

B. 2

C. 3

D. 0

84. For the reversible reaction $A \rightleftharpoons B$, the forward rate constant is 10 and the reverse is 2. What is the equilibrium constant?

A. 20

B. 12

C. 0.2

D. 5

85. At the end of a reaction it catalyses, a catalyst is:

A. Converted into product

B. Consumed entirely

C. Recovered chemically unchanged

D. Transformed into an inhibitor

86. Lowering the activation energy of a reaction:

A. Decreases the reaction rate

B. Has no effect on the rate

C. Increases the rate constant

D. Stops the reaction

Engineering Economics

87. What is the future worth of $6,000 invested for 4 years at 9% interest ($1.09^4 = 1.4116$)?

A. $6,540

B. $7,800

C. $9,000

D. $8,470

88. A vessel costs $300,000 at a capacity of 8 m^3. Using the six-tenths rule, estimate the cost of a 32 m^3 vessel.

A. $1,200,000

B. $300,000

C. $517,000

D. $689,000

89. A project requires $1,000,000 of capital and returns $250,000 per year. What is the simple payback period?

A. 4 yr

B. 2 yr

C. 6 yr

D. 8 yr

90. A project returns $6,000 at the end of each year for 6 years at 8% interest (P/A factor 4.6229). What is its present worth?

A. $27,737

B. $36,000

C. $6,000

D. $48,000

Process Design

91. Which engineering diagram is the earliest, most conceptual representation, showing only major sections as blocks?

A. The P&ID

B. The process flow diagram

C. The block flow diagram

D. The plot plan

92. The purpose of a pinch analysis in process design is to:

A. Size the main reactor

B. Select the reaction catalyst

C. Estimate depreciation

D. Maximise heat recovery and minimise utility use

93. Equipment that cost $90,000 at a cost index of 600 is re-estimated at a current index of 900. What is the updated cost?

A. $60,000

B. $90,000

C. $108,000

D. $135,000

94. As pipe diameter is increased, the pumping cost falls, while:

A. The pipe capital cost rises

B. Both costs fall together

C. Both costs rise together

D. Neither cost changes

95. Maintaining adequate net positive suction head (NPSH) at a pump prevents:

A. Pipe corrosion

B. Pump cavitation

C. Motor overheating

D. Valve leakage

96. A packed tower is most commonly used for which duty?

A. Solid grinding

B. Liquid pumping

C. Gas–liquid contacting such as absorption

D. Heat exchange alone

97. Substituting a less hazardous solvent for a dangerous one is an example of:

A. Inherently safer design

B. Add-on protection

C. An administrative control

D. Emergency response

Process Control

98. A feedback controller takes corrective action:

A. Before any deviation occurs

B. After the controlled variable deviates from setpoint

C. Only on a fixed timer

D. Without any measurement

99. An orifice plate installed in a pipe is used to measure:

A. Temperature

B. Flow rate

C. Liquid level

D. pH

100. Derivative control action is particularly sensitive to:

A. Steady-state offset

B. Slow drift only

C. Constant setpoints

D. Measurement noise

101. Reducing the controller gain generally makes the loop response:

A. More stable but slower

B. Faster but less stable

C. Completely unaffected

D. Instantaneous

Safety, Health, and Environment

102. A vapour–air mixture above its upper flammability limit is:

A. Too lean to ignite

B. Too rich to ignite

C. At its most explosive

D. At its autoignition point

103. Personal protective equipment occupies which position in the hierarchy of controls?

A. The most effective level

B. Above engineering controls

C. Above substitution

D. The least effective, last-resort level

104. The STEL is an exposure limit defined as a:

A. An 8-hour time-weighted average

B. A short-term limit over about 15 minutes

C. A lifetime average exposure

D. An instantaneous ceiling only

105. A spring-loaded relief valve recloses when:

A. The pressure falls below its set point

B. It is manually reset only

C. The vessel has fully emptied

D. Never; it does not reseat

106. Bonding and grounding of equipment that handles flammable liquids prevents:

A. Corrosion of the vessel

B. Overpressure of the system

C. Ignition from static electricity

D. Thermal expansion of the liquid

Ethics and Professional Practice

107. When making public statements in their professional capacity, engineers must ensure those statements are:

A. Objective and truthful

B. Always favourable to the employer

C. Deliberately vague to avoid liability

D. Exaggerated to attract attention

108. Practising only within one's area of competence primarily serves to protect:

A. The public from unqualified work

B. The engineer's salary level

C. The firm's market share

D. The regulator's budget

109. An engineer serving as an impartial reviewer of a project should:

A. Conceal any prior involvement

B. Disclose any prior involvement with the project

C. Approve it as quickly as possible

D. Delegate the review without notice

110. A life-cycle assessment evaluates a product's:

A. Purchase price alone

B. Operating cost alone

C. Environmental impacts from cradle to grave

D. Marketing potential

Practice Exam 11 — Answer Key and Explanations

1. B — Separating $dy/dx = 3y$ gives $y = Ce^{3x}$, exponential growth proportional to the current value. This form describes first-order growth and decay, from population models to first-order reactions.

2. D — The antiderivative of e^x is e^x, evaluated from 0 to 2 as $e^2 - e^0 = 7.39 - 1 = 6.39$. The exponential's self-derivative makes this integral straightforward.

3. A — The identity matrix is the multiplicative identity, so $IA = A$ for any compatible A. It plays the same role for matrices that the number one plays for scalars.

4. C — By the power rule, the derivative of x^3 is $3x^2$. Differentiation multiplies by the exponent and reduces it by one.

5. B — Using the small-angle expansion, $(1 - \cos x) \approx x^2/2$, so the limit is 1/2. This standard result appears in linearising oscillatory and pendulum problems.

6. B — The cross product of parallel vectors is the zero vector, since the sine of the zero angle between them is zero. This vanishing product is the test for parallelism.

7. A — For independent events, the joint probability is the product, $0.4 \times 0.25 = 0.10$. Multiplying applies only when one event does not affect the other.

8. C — The mean is the sum over the count, $(5 + 10 + 15)/3 = 30/3 = 10$. The mean is the data's balance point.

9. D — The number of combinations is $C(8,2) = 8!/(2!6!) = 28$. Combinations count unordered selections.

10. A — Adding a constant shifts every value equally, leaving their spread, and hence the standard deviation, unchanged. Only multiplying the data scales the standard deviation.

11. D — The Poisson probability of one event is $\lambda e^{-\lambda} = 2 \times e^{-2} = 2 \times 0.135 = 0.271$. The Poisson model describes rare random events per interval.

12. D — Kinetic energy is $\frac{1}{2}mv^2 = \frac{1}{2} \times 10 \times 4^2 = 80$ J. The square dependence on velocity makes speed the dominant factor.

13. B — Series resistances add directly, $5 + 10 + 15 = 30\ \Omega$. The series total always exceeds any single resistor.

14. B — Newton's second law gives $F = ma = 5 \times 4 = 20$ N. Force is the product of mass and acceleration.

15. D — Power dissipated is $I^2R = 3^2 \times 4 = 36$ W. This resistive heating sets conductor sizing and cooling needs.

16. A — Elastic deformation is fully recoverable; the material returns to its original shape once the load is removed. Beyond the elastic limit, deformation becomes permanent.

17. C — Brittle materials fracture with little plastic deformation, giving little warning before failure. Their lack of ductility is why brittle failures can be sudden and catastrophic.

18. C — Tempering reheats hardened steel to reduce its brittleness and improve toughness, trading a little hardness for greater resistance to fracture. It produces a more usable balance of properties.

19. B — Stress-corrosion cracking requires both a sustained tensile stress and a corrosive environment acting together. Either alone may be tolerable, but in combination they crack susceptible alloys.

20. D — The glass-transition temperature is where an amorphous polymer changes from a rigid, glassy state to a softer, rubbery one. It marks the onset of large-scale chain mobility, not melting.

21. A — Sodium hydroxide is a strong base that dissociates completely in water, unlike weakly basic ammonia. Complete dissociation gives it a high pH at modest concentration.

22. C — Summing atomic masses, C (12) + 2O (32) = 44 g/mol. Molar mass converts between mass and moles in stoichiometry.

23. C — At constant pressure, Charles's law makes volume proportional to absolute temperature, so doubling 300 K to 600 K doubles the volume to 6 L. This relation governs the thermal expansion of gases.

24. A — Increasing reactant concentration raises the collision frequency and therefore the reaction rate, for positive-order reactions. This is the basis of concentration-based rate control.

25. C — With excess oxygen, the two-to-two stoichiometry converts 6 mol of hydrogen into 6 mol of water. Hydrogen is the limiting reactant and sets the product amount.

26. B — With $[OH^-] = 10^{-2}$, the pOH is 2, so pH = 14 − 2 = 12. The pH and pOH always sum to 14 at 25 °C.

27. D — A heterogeneous catalyst exists in a different phase from the reactants, typically a solid acting on gases or liquids. Reaction occurs at its surface through adsorption and desorption.

28. D — Proteins are polymers of amino acids linked by peptide bonds. The sequence of amino acids determines each protein's structure and function.

29. B — Reynolds number is $\rho vD/\mu = (900 \times 2 \times 0.05)/0.015 = 6000$. This places the flow in the turbulent regime.

30. D — Continuity gives $v_2 = v_1A_1/A_2 = 2 \times 4 = 8$ m/s. Reducing the area to a quarter raises the velocity fourfold.

31. D — By Bernoulli's principle, at a point of higher velocity the static pressure is lower, conserving total head. This inverse relation underlies venturi metering and lift.

32. A — Hydrostatic pressure is $\rho gh = 1000 \times 9.81 \times 3 = 29{,}430$ Pa ≈ 29.4 kPa. Pressure rises linearly with depth.

33. B — For laminar flow, the friction factor is $64/Re = 64/400 = 0.16$. The inverse dependence on Reynolds number gives higher friction at lower flow.

34. A — Ideal hydraulic power is $\rho gQH = 1000 \times 9.81 \times 0.04 \times 12 = 4708.8$ W ≈ 4.71 kW. Dividing by efficiency would give the shaft power.

35. C — Volumetric flow is area times velocity, $0.2 \times 3 = 0.6$ m^3/s. This relation sizes ducts for a target throughput.

36. A — Dynamic viscosity has SI units of pascal-seconds (Pa·s). It measures a fluid's resistance to shear, distinct from the kinematic viscosity in m^2/s.

37. A — The Reynolds number is the ratio of inertial to viscous forces, governing whether flow is laminar or turbulent. A high value means inertia dominates and flow becomes turbulent.

38. C — Carnot efficiency is $1 - T_c/T_h = 1 - 400/1000 = 0.60$, or 60%. The large temperature ratio raises the theoretical ceiling.

39. C — Internal energy change at constant volume is $nC_v\Delta T = 4 \times 20 \times 30 = 2400$ J. The constant-volume heat capacity applies because no expansion work is done.

40. A — The first law gives $\Delta U = Q - W = 1000 - 600 = 400$ J. Heat added that is not spent on work raises the internal energy.

41. B — Adiabatic turbine power is $\dot{m}(h_1 - h_2) = 5 \times (3100 - 2700) = 2000$ kW. The enthalpy drop converts directly into shaft work.

42. A — Refrigerator COP is $Q_c/W = 500/200 = 2.5$. The device moves more heat than the work it consumes, the basis of efficient cooling.

43. D — Raoult's law gives the bubble pressure as $0.5 \times 80 + 0.5 \times 40 = 60$ kPa. The total pressure is the mole-fraction-weighted sum of the pure vapour pressures.

44. D — Entropy is a measure of molecular disorder or the number of accessible microstates. Its increase governs the direction of spontaneous change.

45. C — A process at constant temperature is isothermal, as opposed to adiabatic, isobaric, or isochoric. Isothermal operation requires heat exchange to hold temperature steady.

46. B — An exothermic reaction releases heat, so its heat of reaction is negative. The negative sign denotes energy leaving the system.

47. C — A steady-state mass balance gives bottoms = feed − overhead = 600 − 250 = 350 kg/h. Conservation of mass closes the separation.

48. C — A solids balance gives 0.12 × 1000 = 0.30 × L, so the product is L = 400 kg/h. The non-volatile solids fix the product rate.

49. A — At 2 mol of oxygen per mole of methane, 4 mol of methane requires 4 × 2 = 8 mol. Combustion stoichiometry sets the oxygen demand.

50. C — The combined salt is 0.20 × 150 + 0.60 × 150 = 30 + 90 = 120 kg in 300 kg, giving 40%. A component balance yields the blended composition.

51. B — Conversion is (500 − 125)/500 = 75%. This fraction measures how completely the feed is consumed.

52. B — The recycle ratio is recycle over fresh feed, 400/200 = 2. It characterises the process's reliance on recycling.

53. A — Sensible heat is $mC_p\Delta T$ = 30 × 2 × 25 = 1500 kJ. This relation sizes the heating duty for a temperature change.

54. D — Converting 50% wet basis gives dry basis = 50/(100 − 50) = 100%. The dry basis exceeds the wet basis, here reaching equal masses of water and dry solid.

55. C — The stoichiometry produces four moles of B per mole of A, so 3 mol of A yields 12 mol of B. Reaction stoichiometry converts reactant consumed into product formed.

56. D — Percentage excess is (10 − 8)/8 = 25%. The surplus oxygen ensures complete combustion.

57. B — The first step in a material balance is to choose a calculation basis, such as a fixed amount or time of feed. A clear basis anchors all subsequent stream calculations.

58. C — Fourier's law gives $Q = kA\Delta T/L$ = (3 × 2 × 50)/0.1 = 3000 W. Conductive heat rate scales with conductivity, area, and driving temperature.

59. D — Convective heat rate is $hA\Delta T$ = 60 × 2 × 30 = 3600 W. The coefficient h reflects the effectiveness of fluid motion in removing heat.

60. B — Emissive power scales with the fourth power of absolute temperature, so doubling T raises it by 2^4 = 16 times. This steep dependence makes radiation dominant at high temperatures.

61. D — With $\Delta T_1 = 50$ °C and $\Delta T_2 = 40$ °C, the log-mean is $(50 - 40)/\ln(50/40) = 44.8$ °C. The LMTD, not the arithmetic mean of 45 °C, is the correct driving force.

62. A — Series thermal resistances add directly, 0.3 + 0.4 = 0.7 K/W. The thermal-circuit analogy makes composite-wall analysis straightforward.

63. C — With two equal films of 100 W/m²·K, $1/U = 1/100 + 1/100 = 0.02$, so $U = 50$ W/m²·K. Equal series resistances halve the overall coefficient.

64. A — Exchanger duty is $UA\Delta T = 250 \times 4 \times 20 = 20{,}000$ W = 20 kW. This product of coefficient, area, and driving force sizes the exchanger.

65. B — In a vacuum there is no medium for conduction or convection, so heat transfers only by radiation. This is why thermos flasks use an evacuated gap to limit heat flow.

66. B — Silver is an excellent conductor of heat, far surpassing wood, plastic, and air. Metals conduct heat well through their free electrons.

67. C — Fick's law gives flux = $D \cdot \Delta C/\delta = (1.5 \times 10^{-9} \times 20)/(1 \times 10^{-3}) = 3 \times 10^{-5}$ mol/m²·s. Flux rises with diffusivity and concentration difference and falls with film thickness.

68. A — The vapour–liquid K-value is defined as the ratio y/x of the vapour to liquid mole fractions. It exceeds one for the more volatile component, driving distillation.

69. B — A saturated-vapour feed 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.

70. D — For equal volumes, the fraction extracted is $K/(K + 1) = 4/5 = 0.80$. A higher distribution coefficient drives more solute into the extract.

71. C — The number of transfer units is $\ln(C_{in}/C_{out}) = \ln(7.4) \approx 2.0$. NTU rises with the fractional removal demanded.

72. A — Gas solubility, and hence absorber capacity, rises with increasing pressure, which drives more gas into the liquid. High pressure and low temperature both favour absorption.

73. D — The energy input to reverse osmosis chiefly pressurises the feed above its osmotic pressure, forcing water through the membrane against the concentration gradient. This pressure work is the dominant cost of the process.

74. D — Murphree efficiency is defined for an individual tray, comparing its actual composition change to the ideal equilibrium change. The whole-column figure is the overall efficiency.

75. A — In the two-film theory, the film with the lower mass-transfer coefficient offers the greater resistance and therefore controls the overall rate. Enhancing transfer in that film yields the biggest improvement.

76. B — Stokes' law gives $v = gd^2\Delta\rho/(18\mu) = (9.81 \times (1 \times 10^{-4})^2 \times 2500)/(18 \times 10^{-3}) = 1.36 \times 10^{-2}$ m/s. The square dependence on diameter makes settling highly size-sensitive.

77. D — A higher mesh number means more openings per inch and therefore smaller individual openings. This inverse relation is central to interpreting sieve sizes.

78. B — Cake filtration is driven by the pressure difference applied across the filter medium and the accumulating cake. Raising the pressure increases the rate but compacts the cake.

79. C — Bulk density accounts for both the solid material and the void space between particles, making it lower than the true solid density. It governs the volume that a given mass of powder occupies in a hopper or container.

80. B — First-order decay gives $C = C_0e^{(-kt)} = 5 \times e^{(-0.2 \times 5)} = 5 \times e^{(-1)} = 5 \times 0.368 = 1.84$ mol/L. The concentration falls exponentially at a rate fixed by k.

81. A — For a first-order CSTR, $\tau = X/[k(1 - X)] = 0.5/(0.5 \times 0.5) = 2$ min. The space time links reactor size to the conversion achieved.

82. B — The first-order half-life is $0.693/k = 0.693/0.0462 = 15$ min. This half-life is independent of concentration, the signature of first-order kinetics.

83. C — A rate that rises eightfold when concentration doubles corresponds to $(2)^n = 8$, so $n = 3$, third order. Determining order from concentration–rate data is the standard kinetic method.

84. D — At equilibrium the forward and reverse rates balance, so $K = k_{forward}/k_{reverse} = 10/2 = 5$. This links the kinetic constants to the equilibrium position.

85. C — A catalyst emerges from the reaction chemically unchanged, since it is not consumed. It participates in the mechanism but is regenerated by the end of each cycle.

86. C — Lowering the activation energy increases the rate constant, since fewer molecules need to surmount the barrier at a given temperature. This is precisely how a catalyst accelerates a reaction.

87. D — Future worth is $P(1 + i)^n = 6000 \times 1.09^4 = 6000 \times 1.4116 = \$8,470$. Compounding grows the sum forward at the stated rate.

88. D — The six-tenths rule gives $300,000 \times (32/8)^{0.6} = 300,000 \times 2.297 = \$689,000$. Quadrupling capacity raises cost only about 2.3-fold, the economy of scale.

89. A — Simple payback is capital over annual return, 1,000,000/250,000 = 4 years. The measure is quick but ignores the time value of money.

90. A — Present worth of the annuity is 6000 × 4.6229 = $27,737. The annuity factor sums the discounted value of all six payments.

91. C — The block flow diagram is the earliest, most conceptual representation, showing major sections as connected blocks. It conveys the overall scheme before equipment detail is added.

92. D — Pinch analysis identifies the maximum feasible heat recovery between hot and cold streams, minimising the external utilities required. It is a principal route to lowering a plant's energy cost.

93. D — Updating with the cost index gives 90,000 × (900/600) = $135,000. The index ratio corrects the historical cost for inflation.

94. A — A larger pipe diameter lowers pumping cost by reducing friction but raises the pipe's capital cost. Balancing these opposing trends gives the economic optimum diameter.

95. B — Maintaining adequate net positive suction head keeps the suction pressure above the liquid's vapour pressure, preventing pump cavitation. Cavitation forms damaging vapour bubbles that collapse on the impeller.

96. C — A packed tower is commonly used for gas–liquid contacting operations such as absorption and stripping, where the packing provides surface area for mass transfer. Its low pressure drop suits gas-handling duties.

97. A — Substituting a less hazardous solvent removes or reduces the hazard at the source, the essence of inherently safer design. It is more reliable than adding protective layers around a dangerous material.

98. B — A feedback controller responds after the controlled variable deviates from setpoint, using the measured error to drive correction. It corrects disturbances only once their effect appears.

99. B — An orifice plate measures flow rate by relating it to the pressure drop across the restriction. It is a simple, widely used differential-pressure flow device.

100. D — Derivative action responds to the rate of change of the error and is therefore highly sensitive to measurement noise, which it amplifies. Filtering the signal is often needed to use derivative action effectively.

101. A — Reducing the controller gain makes the loop more stable but slower to respond, since each correction is gentler. Tuning trades response speed against stability.

102. B — Above the upper flammability limit a mixture is too rich to ignite, lacking sufficient oxygen relative to fuel. Both this and the too-lean condition fall outside the flammable range.

103. D — Personal protective equipment is the least effective, last-resort tier of the hierarchy of controls, because it relies on correct human use. Elimination and engineering controls are preferred wherever possible.

104. B — The short-term exposure limit is a maximum permitted exposure averaged over a short period, typically 15 minutes. It guards against acute effects that an eight-hour average could mask.

105. A — A spring-loaded relief valve recloses once the pressure falls below its set point, unlike a rupture disc. This reseating ability allows the system to return to normal operation after a transient.

106. C — Bonding and grounding equalise electrical potential and provide a path to earth, preventing the accumulation of static charge that could ignite flammable vapours. Static-spark ignition is a common cause of fires in liquid handling.

107. A — Engineers must make public statements that are objective and truthful, not biased by employer interest or exaggeration. Honest public communication protects the public and the profession's credibility.

108. A — Practising only within one's competence protects the public from unqualified or unsafe work. This duty ensures that those affected by an engineer's work are served by adequate expertise.

109. B — An impartial reviewer must disclose any prior involvement with the project, since it could bias the assessment. Disclosure preserves the integrity and credibility of the review.

110. C — A life-cycle assessment evaluates a product's environmental impacts from raw-material extraction through manufacture, use, and disposal — cradle to grave. This whole-life view is central to sustainable design.