PRACTICE EXAM 15: FE CHEMICAL SIMULATION (110 QUESTIONS)

Mathematics

1. What is the general solution of the differential equation $y'' - 4y = 0$?

A. $y = C_1\cos(2x) + C_2\sin(2x)$

B. $y = C_1e^{(2x)} + C_2e^{(-2x)}$

C. $y = (C_1 + C_2x)e^{(2x)}$

D. $y = C_1e^{(4x)}$

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

A. 1

B. e

C. 0

D. $e - 1$

3. The transpose of a matrix is formed by:

A. Interchanging its rows and columns

B. Negating all of its entries

C. Inverting the matrix

D. Squaring the matrix

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

A. x^3

B. $4x^3$

C. $4x^4$

D. $x^5/5$

5. Evaluate the limit of tan(x)/x as x approaches 0.

A. 0

B. Infinity

C. Undefined

D. 1

6. The dot product of a vector with itself equals:

A. The square of its magnitude

B. Zero

C. One

D. Its direction

Probability and Statistics

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

A. 0.25

B. 0.077

C. 0.50

D. 0.038

8. What is the range of the data set 5, 12, 8, 20, and 15?

A. 12

B. 20

C. 15

D. 60

9. In how many ways can 3 items be chosen from 6 distinct items, where order does not matter?

A. 120

B. 18

C. 36

D. 20

10. The variance of a data set is the average of the:

A. Absolute deviations

B. Raw values

C. Medians

D. Squared deviations from the mean

11. A game pays $10 with probability 0.3 and loses $2 with probability 0.7. What is the expected value per play?

A. $8

B. $3

C. $1.60

D. $10

Engineering Sciences

12. A constant 50 N force moves an object 8 m in the direction of the force. How much work is done?

A. 400 J

B. 6.25 J

C. 58 J

D. 42 J

13. Two 6 Ω resistors are connected in parallel. What is the equivalent resistance?

A. 3 Ω

B. 12 Ω

C. 6 Ω

D. 0.33 Ω

14. A 60 N net force acts on a 15 kg mass. What is the resulting acceleration?

A. 900 m/s²

B. 0.25 m/s²

C. 75 m/s²

D. 4 m/s²

15. A device draws 5 A at 24 V. What electrical power does it consume?

A. 4.8 W

B. 29 W

C. 120 W

D. 19 W

Materials Science

16. The ability of a material to absorb energy and deform plastically before fracturing is its:

A. Hardness

B. Stiffness

C. Brittleness

D. Toughness

17. Rapidly quenching steel from a high temperature produces:

A. A soft, ductile structure

B. A hard, brittle martensitic structure

C. A fully molten phase

D. A corrosion-proof coating

18. A finer grain size generally gives a metal:

A. Higher strength and toughness

B. Lower strength

C. No change in properties

D. A lower melting point

19. Cathodic protection prevents corrosion by:

A. Making the protected metal the cathode

B. Raising its temperature

C. Permanently removing all oxygen

D. Painting it white

20. A thermoplastic differs from a thermoset in that it:

A. Cannot be melted at all

B. Is always a metal

C. Forms permanent cross-links on heating

D. Can be remelted and reshaped repeatedly

Chemistry and Biology

21. An aqueous solution has a hydrogen ion concentration of 1×10^{-4} mol/L. What is its pH?

A. 10

B. 1×10^{-4}

C. 4

D. 7

22. What is the molar mass of carbon monoxide, CO?

A. 16 g/mol

B. 28 g/mol

C. 44 g/mol

D. 12 g/mol

23. A fixed quantity of gas at 3 atm has its absolute temperature doubled at constant volume. What is the new pressure?

A. 1.5 atm

B. 3 atm

C. 1 atm

D. 6 atm

24. A catalyst accelerates a reaction by providing:

A. An alternative pathway with lower activation energy

B. Additional reactant

C. Extra heat to the system

D. A higher equilibrium constant

25. The decomposition $CaCO_3 \rightarrow CaO + CO_2$ proceeds to completion. How many moles of CO_2 form from 5 mol of calcium carbonate?

A. 10 mol

B. 2.5 mol

C. 1 mol

D. 5 mol

26. What is the molarity of a solution containing 2 mol of solute in 4 L of solution?

A. 8 M

B. 2 M

C. 0.5 M

D. 4 M

27. A covalent bond is formed by:

A. Transferring electrons between atoms

B. A sea of delocalised metallic electrons

C. Magnetic attraction

D. Sharing electron pairs between atoms

28. Photosynthesis converts carbon dioxide and water into glucose using:

A. Light energy

B. Heat alone

C. Electrical energy

D. Sound energy

Fluid Mechanics

29. A fluid (density 1200 kg/m³, viscosity 0.006 Pa·s) flows at 0.5 m/s through a 0.08 m pipe. What is the Reynolds number?

A. 8000

B. 800

C. 80000

D. 1600

30. Flow at 2 m/s in a 0.1 m² duct enters a 0.025 m² section. What is the velocity in the smaller section?

A. 0.5 m/s

B. 2 m/s

C. 8 m/s

D. 4 m/s

31. Along a horizontal streamline where the velocity decreases, the static pressure:

A. Increases

B. Decreases

C. Stays constant

D. Drops to zero

32. What is the hydrostatic pressure at a depth of 8 m in water (density 1000 kg/m³)?

A. 8 kPa

B. 78.5 kPa

C. 785 kPa

D. 7.85 kPa

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

A. 64

B. 3.2

C. 0.2

D. 0.02

34. A pump delivers 0.04 m³/s of water against a head of 15 m. What is the ideal hydraulic power?

A. 0.59 kW

B. 58.9 kW

C. 5.89 kW

D. 589 W

35. A flow of 0.9 m^3/s passes through a duct of cross-sectional area 0.3 m^2. What is the velocity?

A. 0.33 m/s

B. 0.27 m/s

C. 30 m/s

D. 3 m/s

36. Using the Darcy equation with f = 0.025, L = 40 m, D = 0.05 m, and v = 2 m/s, what is the head loss?

A. 2.04 m

B. 4.08 m

C. 8.16 m

D. 1.02 m

37. Viscosity is a measure of a fluid's:

A. Density

B. Resistance to shear or flow

C. Compressibility

D. Boiling point

Thermodynamics

38. A Carnot engine operates between 1000 K and 250 K. What is its maximum efficiency?

A. 25%

B. 50%

C. 75%

D. 40%

39. Four moles of an ideal gas (Cv = 15 J/mol·K) are heated by 10 K at constant volume. What is the change in internal energy?

A. 300 J

B. 600 J

C. 1200 J

D. 150 J

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

A. 500 J

B. 1100 J

C. −500 J

D. 800 J

41. Steam enters an adiabatic turbine at 3400 kJ/kg and leaves at 2900 kJ/kg, flowing at 3 kg/s. What is the shaft power?

A. 500 kW

B. 1000 kW

C. 1500 kW

D. 3000 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. 3.5

C. 0.4

D. 2.5

43. An equimolar liquid mixture of A (pure vapour pressure 140 kPa) and B (60 kPa) follows Raoult's law. What is the bubble-point pressure?

A. 60 kPa

B. 100 kPa

C. 140 kPa

D. 200 kPa

44. For an exothermic reaction, the products have:

A. Higher enthalpy than the reactants

B. Lower enthalpy than the reactants

C. Equal enthalpy

D. Zero enthalpy

45. Mixing two different gases at constant temperature causes the total entropy to:

A. Decrease

B. Stay constant

C. Become zero

D. Increase

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

A. Spontaneous at all temperatures

B. Spontaneous at high temperature

C. Spontaneous at low temperature

D. Never spontaneous

Material and Energy Balances

47. A 1200 kg/h feed is split into a 500 kg/h top product and a bottom product. What is the bottom flow rate?

A. 1700 kg/h

B. 700 kg/h

C. 500 kg/h

D. 1200 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. 280 kg/h

49. Combustion follows $2CO + O_2 \rightarrow 2CO_2$. How many moles of oxygen are needed for 8 mol of carbon monoxide?

A. 8 mol

B. 16 mol

C. 4 mol

D. 2 mol

50. A 200 kg stream of 10% salt is mixed with a 300 kg stream of 60% salt. What is the salt content of the mixture?

A. 10%

B. 60%

C. 35%

D. 40%

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 600 mol/h and receives a fresh feed of 200 mol/h. What is the recycle ratio?

A. 0.33

B. 1

C. 3

D. 800

53. How much heat is required to raise 30 kg of water by 25 °C, with a specific heat of 4.18 kJ/kg·K?

A. 784 kJ

B. 1568 kJ

C. 4180 kJ

D. 3135 kJ

54. A solid has a moisture content of 40% on a dry basis. What is the equivalent moisture content on a wet basis?

A. 28.6%

B. 40%

C. 60%

D. 66.7%

55. In the reaction $2A \rightarrow B$, 8 mol of A reacts completely. How many moles of B are formed?

A. 4 mol

B. 8 mol

C. 16 mol

D. 2 mol

56. A burner needs 16 mol of oxygen stoichiometrically but is supplied with 20 mol. What is the percentage excess oxygen?

A. 20%

B. 80%

C. 25%

D. 125%

57. A purge stream is introduced into a recycle loop in order to:

A. Increase conversion directly

B. Add fresh catalyst

C. Cool the reactor

D. Prevent the build-up of inerts

Heat Transfer

58. A 0.15 m thick wall (k = 1.5 W/m·K, area 3 m²) has a 50 °C temperature difference across it. What is the conductive heat rate?

A. 750 W

B. 1500 W

C. 3000 W

D. 500 W

59. A 2 m² surface transfers heat by convection with h = 50 W/m²·K and a temperature difference of 10 °C. What is the heat rate?

A. 1000 W

B. 500 W

C. 2000 W

D. 250 W

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

A. 16×

B. 64×

C. 256×

D. 4×

61. In a counter-current exchanger, the hot stream cools from 120 °C to 80 °C while the cold stream warms from 40 °C to 60 °C. What is the log-mean temperature difference?

A. 50 °C

B. 49.3 °C

C. 45 °C

D. 40 °C

62. Two wall layers have thermal resistances of 0.3 K/W and 0.7 K/W in series. What is the total resistance?

A. 0.21 K/W

B. 0.5 K/W

C. 0.4 K/W

D. 1.0 K/W

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

A. 200 W/m²·K

B. 450 W/m²·K

C. 900 W/m²·K

D. 100 W/m²·K

64. An exchanger has U = 400 W/m²·K, area 5 m², and a log-mean temperature difference of 20 °C. What is the heat duty?

A. 40 kW

B. 20 kW

C. 80 kW

D. 10 kW

65. Unlike conduction and convection, radiation can transfer heat through:

A. Only solids

B. Only liquids

C. Only gases

D. A vacuum

66. Among the following, the best thermal conductor is:

A. Wood

B. Copper

C. Glass

D. Air

Mass Transfer and Separation

67. A species diffuses through a 3 mm film with $D = 5 \times 10^{-9}$ m²/s and a concentration difference of 12 mol/m³. What is the molar flux?

A. 6×10^{-5} mol/m²·s

B. 1.5×10^{-5} mol/m²·s

C. 3×10^{-5} mol/m²·s

D. 2×10^{-5} mol/m²·s

68. The equilibrium ratio K = y/x for a component exceeds one when the component is:

A. More volatile

B. Less volatile

C. Non-volatile

D. Inert

69. For a saturated-liquid feed to a distillation column, the q-value equals:

A. 0

B. 1

C. Infinity

D. −1

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

A. 0.50

B. 0.67

C. 0.33

D. 0.25

71. A packed column has an HTU of 0.6 m and requires 5 transfer units. What is the packed height?

A. 0.6 m

B. 5 m

C. 8.3 m

D. 3.0 m

72. Increasing the liquid flow rate in a gas absorber generally:

A. Reduces solute removal

B. Has no effect

C. Improves solute removal

D. Floods the column immediately

73. Gas-phase diffusivities are typically:

A. Much larger than liquid-phase diffusivities

B. Much smaller than liquid-phase diffusivities

C. Equal to liquid-phase diffusivities

D. Always zero

74. The component that concentrates in the distillate of a column is the:

A. Heavier component

B. More volatile (lighter) component

C. Non-volatile residue

D. Inert carrier

75. The wet-bulb temperature of unsaturated air is always:

A. Higher than the dry-bulb temperature

B. Equal to the boiling point

C. Lower than or equal to the dry-bulb temperature

D. Independent of humidity

Solids Handling

76. A 200 μm particle ($\Delta\rho = 1200$ kg/m³) settles in a fluid of viscosity 2×10^{-3} Pa·s. What is its Stokes' law terminal velocity?

A. 6.5×10^{-3} m/s

B. 1.31×10^{-2} m/s

C. 2.6×10^{-2} m/s

D. 3.9×10^{-3} m/s

77. In cake filtration at constant pressure, as the cake thickens the filtration rate:

A. Increases

B. Stays constant

C. Becomes infinite

D. Decreases

78. The energy required for size reduction increases as the:

A. Product size increases

B. Feed rate decreases

C. Product particle size decreases

D. Moisture content rises

79. A screw conveyor moves solids by:

A. Blowing air through a duct

B. Rotating a helical flight within a trough

C. Vibrating a flat tray

D. Magnetic levitation

Chemical Reaction Engineering

80. A first-order reaction ($k = 0.4$ min^{-1}) starts at 5 mol/L. What is the concentration after 2.5 minutes, using $C = C_0e^{(-kt)}$?

A. 2.5 mol/L

B. 1.84 mol/L

C. 0.74 mol/L

D. 0.37 mol/L

81. A first-order reaction ($k = 0.3\ min^{-1}$) runs in a PFR with a space time of 10 minutes. What conversion is achieved, using $X = 1 - e^{(-k\tau)}$?

A. 0.63

B. 0.78

C. 0.86

D. 0.95

82. A first-order reaction ($k = 0.2\ min^{-1}$) reaches 80% conversion in a CSTR. What space time is required?

A. 4 min

B. 10 min

C. 20 min

D. 5 min

83. A first-order reaction has a rate constant of $0.0231\ min^{-1}$. What is its half-life, $t_{½} = 0.693/k$?

A. 30 min

B. 15 min

C. 60 min

D. 10 min

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

A. Zero order

B. First order

C. Second order

D. Third order

85. For the reversible reaction A ⇌ B, the forward rate constant is 24 and the reverse is 6. What is the equilibrium constant?

A. 30

B. 18

C. 4

D. 0.25

86. Raising the temperature of an exothermic reaction shifts the equilibrium toward:

A. The reactants, lowering conversion

B. The products, raising conversion

C. No change at all

D. Complete reaction

Engineering Economics

87. What is the future worth of $8,000 invested for 5 years at 5% interest ($1.05^5 = 1.2763$)?

A. $9,200

B. $9,800

C. $10,210

D. $12,000

88. What is the present worth of $30,000 to be received in 3 years at 8% interest ($1.08^3 = 1.2597$)?

A. $27,000

B. $23,815

C. $30,000

D. $37,791

89. A $100,000 asset with a $20,000 salvage value is depreciated straight-line over 8 years. What is the annual depreciation?

A. $12,500

B. $11,000

C. $80,000

D. $10,000

90. A project requires $900,000 of capital and returns $225,000 per year. What is the simple payback period?

A. 2 yr

B. 4 yr

C. 6 yr

D. 3 yr

Process Design

91. The largest single contributor to a chemical plant's fixed capital cost is usually the:

A. Purchased equipment

B. Office supplies

C. Land alone

D. Annual labour

92. The minimum number of theoretical stages in a distillation column occurs at:

A. Minimum reflux

B. Total reflux

C. Zero reflux

D. The feed stage

93. Equipment that cost $90,000 at a cost index of 500 is re-estimated at a current index of 750. What is the updated cost?

A. $60,000

B. $90,000

C. $112,500

D. $135,000

94. The economic optimum pipe diameter is found by balancing pumping cost against:

A. Valve cost alone

B. Labour cost

C. Insulation cost

D. Pipe capital cost

95. A vessel used to separate vapour from liquid by reducing pressure is a:

A. Reboiler

B. Flash drum

C. Heat exchanger

D. Pump

96. For cryogenic service at very low temperature, a suitable material of construction is:

A. Austenitic stainless steel

B. Ordinary carbon steel

C. Cast iron

D. Lead

97. The primary purpose of a bursting (rupture) disc is to:

A. Measure flow rate

B. Provide rapid overpressure relief

C. Control temperature

D. Mix two streams

Process Control

98. A PID controller combines proportional, integral, and:

A. On–off action

B. Cascade action

C. Derivative action

D. Ratio action

99. A pressure transmitter typically converts the measured pressure into a:

A. Standard 4–20 mA signal

B. Visible colour change

C. Sound wave

D. Mechanical rotation alone

100. Reducing the gain of a controller generally makes the loop:

A. More stable but slower to respond

B. Faster and less stable

C. Unaffected

D. Permanently unstable

101. In cascade control, the output of the primary controller becomes the:

A. Final valve position directly

B. Measured disturbance

C. Set point of the secondary controller

D. Process alarm

Safety, Health, and Environment

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

A. Begins to boil

B. Forms a flammable vapour only

C. Ignites without an external spark

D. Freezes solid

103. Within the hierarchy of safety measures, the most reliable layer is:

A. Inherent safety through design

B. Personal protective equipment

C. Emergency procedures

D. Warning signs

104. A time-weighted average exposure limit is normally based on an:

A. 1-hour period

B. Single breath

C. 24-hour day

D. 8-hour working day

105. To prevent static-electricity discharge during a liquid transfer, the containers should be:

A. Heated first

B. Filled rapidly

C. Bonded and grounded

D. Left open to the air

106. A baghouse is used principally to remove:

A. Particulate matter from a gas stream

B. Dissolved salts from water

C. Heat from steam

D. Odours from liquids

Ethics and Professional Practice

107. When a cost-saving conflicts with public safety, the engineer must:

A. Choose the cheaper option

B. Defer entirely to the client

C. Prioritise public safety over the saving

D. Ignore the conflict

108. Accepting a substantial gift from a supplier currently bidding on a contract is:

A. Always acceptable

B. A conflict of interest to be avoided

C. Required by custom

D. Irrelevant to ethics

109. An engineer's qualifications stated on a proposal or résumé must be:

A. Inflated to win work

B. Omitted entirely

C. Stated truthfully without exaggeration

D. Copied from a colleague

110. On discovering that a plant is illegally discharging a pollutant, the engineer should:

A. Ignore it as not their concern

B. Conceal it to protect the employer

C. Delay until the next audit

D. Report it through appropriate channels

Practice Exam 15 — Answer Key and Explanations

1. B — The characteristic equation $r^2 - 4 = 0$ gives real roots $r = \pm 2$, producing the solution $C_1e^{(2x)} + C_2e^{(-2x)}$. Distinct real roots always yield a sum of two exponentials.

2. A — The antiderivative of $1/x$ is $\ln(x)$, evaluated from 1 to e as $\ln e - \ln 1 = 1 - 0 = 1$. The natural log is defined so that this area equals one.

3. A — The transpose is formed by interchanging rows and columns, so the element in row i, column j moves to row j, column i. It reflects the matrix across its main diagonal.

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

5. D — The limit of $\tan(x)/x$ as $x \to 0$ is 1, since $\tan(x) \approx x$ for small angles. This mirrors the small-angle result for sine.

6. A — The dot product of a vector with itself equals the sum of its squared components, which is the square of its magnitude. This relation is the basis for computing vector length.

7. B — A standard deck holds 4 aces among 52 cards, giving $4/52 = 0.077$. The four equally likely aces set this probability.

8. C — The range is the largest value minus the smallest, $20 - 5 = 15$. It is the simplest measure of the spread of the data.

9. D — The number of combinations is $C(6,3) = 6!/(3!3!) = 20$. Combinations count unordered selections.

10. D — The variance is the average of the squared deviations from the mean. Squaring removes the sign and weights larger deviations more heavily.

11. C — The expected value is $0.3 \times 10 - 0.7 \times 2 = 3 - 1.4 = \$1.60$. It is the probability-weighted average of the outcomes.

12. A — Work is force times distance, $50 \times 8 = 400$ J. The force acts along the direction of motion, so all of it does work.

13. A — Two equal resistors in parallel give half the value, $6/2 = 3\ \Omega$. The parallel result is always less than either individual resistor.

14. D — Newton's second law gives $a = F/m = 60/15 = 4\ m/s^2$. Acceleration is the net force divided by the mass.

15. C — Electrical power is current times voltage, $P = IV = 5 \times 24 = 120$ W. This relation governs the power drawn by a device.

16. D — Toughness is the ability to absorb energy and deform plastically before fracture, represented by the area under the stress–strain curve. It combines strength with ductility, unlike hardness or stiffness alone.

17. B — Rapid quenching traps carbon and forms hard, brittle martensite by preventing the diffusion that would otherwise yield softer phases. Tempering afterwards restores some toughness.

18. A — A finer grain size raises both strength and toughness, because the many grain boundaries impede dislocation movement and crack propagation. This is the basis of grain-refinement strengthening.

19. A — Cathodic protection makes the protected structure the cathode of an electrochemical cell, so it no longer corrodes as an anode. A sacrificial anode or impressed current supplies the protective electrons.

20. D — A thermoplastic can be melted and reshaped repeatedly because its chains are not chemically cross-linked. A thermoset forms permanent cross-links on curing and cannot be remelted.

21. C — With $[H^+] = 10^{-4}$, the pH is $-\log(10^{-4}) = 4$. This value is acidic, well below neutral.

22. B — Summing atomic masses, C (12) + O (16) = 28 g/mol. Molar mass converts between mass and moles in stoichiometry.

23. D — By Gay-Lussac's law at constant volume, pressure is proportional to absolute temperature, so doubling the temperature doubles 3 atm to 6 atm. Heating a fixed volume of gas raises its pressure.

24. A — A catalyst provides an alternative reaction pathway with a lower activation energy, allowing more molecules to react at a given temperature. It does not change the reactants, energetics, or equilibrium position.

25. D — The one-to-one stoichiometry releases one mole of carbon dioxide per mole of calcium carbonate, so 5 mol yields 5 mol. The decomposition conserves the carbon atoms.

26. C — Molarity is moles over litres, 2/4 = 0.5 M. Concentration relates the amount of solute to the solution volume.

27. D — A covalent bond forms by the sharing of electron pairs between atoms, giving each a stable configuration. This contrasts with the electron transfer of an ionic bond.

28. A — Photosynthesis uses light energy to drive the conversion of carbon dioxide and water into glucose and oxygen. Chlorophyll captures the light that powers this energy-storing reaction.

29. A — Reynolds number is $\rho v D/\mu = (1200 \times 0.5 \times 0.08)/0.006 = 8000$. This turbulent value sets the appropriate friction correlation.

30. C — Continuity gives $v_2 = v_1 A_1/A_2 = 2 \times (0.1/0.025) = 8$ m/s. The fourfold area reduction quadruples the velocity.

31. A — By Bernoulli's principle, where the velocity decreases the static pressure increases, conserving total head. This pressure recovery occurs in a diffuser.

32. B — Hydrostatic pressure is $\rho gh = 1000 \times 9.81 \times 8 = 78{,}480$ Pa ≈ 78.5 kPa. Pressure rises linearly with depth.

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

34. C — Ideal hydraulic power is $\rho gQH = 1000 \times 9.81 \times 0.04 \times 15 = 5886$ W ≈ 5.89 kW. Dividing by efficiency would give the shaft power.

35. D — Velocity is flow over area, $0.9/0.3 = 3$ m/s. This follows directly from the continuity equation.

36. B — The Darcy equation gives $h_f = f(L/D)(v^2/2g) = 0.025 \times (40/0.05) \times (4/19.62) = 4.08$ m. Friction head loss scales with the square of velocity.

37. B — Viscosity measures a fluid's internal resistance to shear, that is, to flow. A high viscosity means the fluid resists deformation and flows slowly.

38. C — Carnot efficiency is $1 - T_c/T_h = 1 - 250/1000 = 0.75$, or 75%. The large temperature ratio raises the theoretical ceiling.

39. B — Internal energy change at constant volume is $nC_v\Delta T = 4 \times 15 \times 10 = 600$ J. The constant-volume heat capacity applies because no work is done.

40. A — 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. C — Adiabatic turbine power is $\dot{m}(h_1 - h_2) = 3 \times (3400 - 2900) = 1500$ kW. The enthalpy drop converts directly into shaft work.

42. D — 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 $0.5 \times 140 + 0.5 \times 60 = 100$ kPa. The total pressure is the mole-fraction-weighted sum of the pure vapour pressures.

44. B — In an exothermic reaction the products lie at lower enthalpy than the reactants, the difference being released as heat. The negative heat of reaction reflects this drop in stored energy.

45. D — Mixing two different gases increases the total entropy, since the molecules disperse into a larger combined volume with more accessible arrangements. This entropy of mixing drives the spontaneous intermingling.

46. D — With ΔH positive and ΔS negative, $\Delta G = \Delta H - T\Delta S$ is positive at every temperature, so the reaction is never spontaneous. Both terms work against the products.

47. B — A steady-state mass balance gives the bottom product as $1200 - 500 = 700$ kg/h. Conservation of mass closes the separation.

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

49. C — At one mole of oxygen per two of carbon monoxide, 8 mol of CO requires $8/2 = 4$ mol. Combustion stoichiometry sets the oxygen demand.

50. D — The combined salt is $0.10 \times 200 + 0.60 \times 300 = 20 + 180 = 200$ kg in 500 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. C — The recycle ratio is recycle over fresh feed, $600/200 = 3$. It characterises the process's reliance on recycling.

53. D — Sensible heat is $mC_p\Delta T = 30 \times 4.18 \times 25 = 3135$ kJ. This relation sizes the heating duty for a temperature change.

54. A — Converting 40% dry basis gives wet basis $= 40/(100 + 40) = 28.6\%$. The wet basis is the smaller figure because its denominator includes the water.

55. A — The stoichiometry consumes two moles of A per mole of B, so 8 mol of A yields 4 mol of B. Reaction stoichiometry converts reactant consumed into product formed.

56. C — Percentage excess is $(20 - 16)/16 = 25\%$. The surplus oxygen ensures complete combustion.

57. D — A purge stream bleeds off part of the recycle to prevent inert or unreactive species from accumulating in the loop. Without it, inerts would build up and eventually disrupt the process.

58. B — Fourier's law gives $Q = kA\Delta T/L = (1.5 \times 3 \times 50)/0.15 = 1500$ W. Conductive heat rate scales with conductivity, area, and driving temperature.

59. A — Convective heat rate is $hA\Delta T = 50 \times 2 \times 10 = 1000$ W. The coefficient h reflects how effectively the fluid removes heat.

60. C — Emissive power scales with the fourth power of absolute temperature, so quadrupling T raises it by $4^4 = 256$ times. This steep dependence makes radiation dominant at high temperatures.

61. B — With $\Delta T_1 = 120 - 60 = 60$ °C and $\Delta T_2 = 80 - 40 = 40$ °C, the log-mean is $(60 - 40)/\ln(60/40) = 49.3$ °C. The LMTD is the correct mean driving force, just below the arithmetic mean of 50 °C.

62. D — Series thermal resistances add directly, 0.3 + 0.7 = 1.0 K/W. The thermal-circuit analogy makes composite-wall analysis straightforward.

63. A — With negligible wall resistance, 1/U = 1/300 + 1/600 = 0.005, so U = 200 W/m²·K. The overall coefficient is smaller than either film coefficient.

64. A — Exchanger duty is $UA\Delta T = 400 \times 5 \times 20 = 40{,}000$ W = 40 kW. This product of coefficient, area, and driving force sizes the exchanger.

65. D — Radiation alone can transfer heat through a vacuum, since it travels as electromagnetic waves needing no medium. Conduction and convection both require matter.

66. B — Copper is an excellent thermal conductor, far exceeding wood, glass, or air. Metals conduct heat well through their free electrons.

67. D — Fick's law gives flux = $D \cdot \Delta C/\delta = (5 \times 10^{-9} \times 12)/(3 \times 10^{-3}) = 2 \times 10^{-5}$ mol/m²·s. Flux rises with diffusivity and concentration difference and falls with film thickness.

68. A — The equilibrium ratio K = y/x exceeds one for the more volatile component, which concentrates in the vapour. This preferential vaporisation drives distillation.

69. B — A saturated-liquid feed has a q-value of 1, since all of it is liquid at its boiling point. The q-value fixes the slope of the feed line on a McCabe–Thiele diagram.

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

71. D — The packed height is HTU × NTU = 0.6 × 5 = 3.0 m. The height of a transfer unit multiplied by the number of units gives the required packing depth.

72. C — Increasing the liquid flow rate in an absorber improves solute removal by providing more solvent to dissolve the gas and a steeper driving force. Excessive flow, however, risks flooding.

73. A — Gas-phase diffusivities are typically several orders of magnitude larger than liquid-phase diffusivities, since gas molecules are far more widely spaced. This makes liquid-side resistance often controlling.

74. B — The more volatile, lighter component concentrates in the overhead distillate, while the heavier component collects in the bottoms. Relative volatility governs this separation.

75. C — The wet-bulb temperature is always lower than or equal to the dry-bulb temperature, the two being equal only at saturation. Evaporative cooling depresses the wet-bulb reading below the dry-bulb.

76. B — Stokes' law gives $v = gd^2\Delta\rho/(18\mu) = (9.81 \times (2 \times 10^{-4})^2 \times 1200)/(18 \times 2 \times 10^{-3}) = 1.31 \times 10^{-2}$ m/s. The square dependence on diameter makes settling highly size-sensitive.

77. D — In constant-pressure cake filtration, the growing cake adds resistance, so the filtration rate decreases with time. A larger cake means a longer path for the filtrate to flow through.

78. C — The energy needed for size reduction rises as the target product size falls, since creating more fine surface demands more work. This makes very fine grinding energy-intensive.

79. B — A screw conveyor moves bulk solids by rotating a helical flight, or auger, inside an enclosed trough, pushing material along its length. It suits short, contained transfers of granular material.

80. B — First-order decay gives $C = C_0 e^{(-kt)} = 5 \times e^{(-0.4 \times 2.5)} = 5 \times e^{(-1)} = 5 \times 0.368 = 1.84$ mol/L. The concentration falls exponentially at a rate fixed by k.

81. D — For a first-order PFR, conversion is $X = 1 - e^{(-k\tau)} = 1 - e^{(-0.3 \times 10)} = 1 - e^{(-3)} = 0.95$. The plug-flow reactor reaches high conversion efficiently.

82. C — For a first-order CSTR, $\tau = X/[k(1 - X)] = 0.8/(0.2 \times 0.2) = 20$ min. High conversion in a CSTR demands a long residence time because it operates at the low exit concentration.

83. 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.

84. C — A rate constant with units of L/(mol·s) corresponds to a second-order reaction, whose rate depends on concentration squared. The units of k reveal the overall reaction order.

85. C — At equilibrium the forward and reverse rates balance, so $K = k_{forward}/k_{reverse} = 24/6 = 4$. This links the kinetic constants to the equilibrium position.

86. A — Raising the temperature of an exothermic reaction shifts the equilibrium toward the reactants, lowering the equilibrium conversion, by Le Chatelier's principle. The added heat is treated as a product that the system consumes.

87. C — Future worth is $P(1 + i)^n = 8000 \times 1.05^5 = 8000 \times 1.2763 = \$10{,}210$. Compounding grows the sum forward at the stated rate.

88. B — Present worth is $F/(1 + i)^n = 30{,}000/1.08^3 = 30{,}000/1.2597 = \$23{,}815$. Discounting reflects that a future sum is worth less today.

89. D — Straight-line depreciation is $(100{,}000 - 20{,}000)/8 = \$10{,}000$ per year. This even allocation spreads the depreciable basis across the service life.

90. B — Simple payback is capital over annual return, $900{,}000/225{,}000 = 4$ years. The measure is quick but ignores the time value of money.

91. A — Purchased equipment is usually the largest single component of a plant's fixed capital cost, and most other costs are estimated as factors of it. This makes accurate equipment costing central to estimating.

92. B — The minimum number of theoretical stages occurs at total reflux, where no product is withdrawn and the operating lines coincide with the diagonal. This sets one limit of column operation.

93. D — Updating with the cost index gives 90,000 × (750/500) = $135,000. The index ratio corrects the historical cost for inflation.

94. D — The optimum pipe diameter balances the falling pumping cost of a larger pipe against its rising capital cost. The economic diameter minimises the sum of these opposing costs.

95. B — A flash drum separates vapour from liquid by dropping the pressure so that part of the feed vaporises and disengages. It is a simple single-stage separation.

96. A — Austenitic stainless steel retains toughness at cryogenic temperatures, unlike carbon steel and cast iron, which turn brittle. Its face-centred cubic structure avoids the ductile-to-brittle transition.

97. B — A bursting disc provides rapid, full-bore overpressure relief, rupturing instantly at its set pressure. It is a non-reclosing device often used where fast relief or isolation from the process is needed.

98. C — A PID controller combines proportional, integral, and derivative actions, blending immediate response, offset elimination, and anticipation. Together they give fast, stable, offset-free control.

99. A — A pressure transmitter converts the measured pressure into a standard 4–20 mA current signal for transmission to the control system. This standard signal resists noise over long wiring runs.

100. 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.

101. C — In cascade control, the primary (outer) controller's output sets the set point of the secondary (inner) controller. The inner loop rejects disturbances quickly before they reach the outer variable.

102. C — The autoignition temperature is the lowest temperature at which a substance ignites spontaneously without an external spark or flame. Above it, the heat of the surroundings alone initiates combustion.

103. A — Inherent safety through design is the most reliable layer, because it removes or reduces the hazard at its source rather than guarding against it. Lower tiers like PPE depend on correct human action.

104. D — A time-weighted average exposure limit is normally based on an 8-hour working day, representing the average concentration a worker may be exposed to over a shift. Short-term limits cover briefer peaks.

105. C — Bonding and grounding equalise electrical potential and provide a path to earth, preventing the static charge build-up that could spark and ignite flammable vapours. Static ignition is a frequent cause of transfer fires.

106. A — A baghouse removes particulate matter from a gas stream by passing it through fabric filter bags that capture the solids. It is a widely used dust-collection device for air-pollution control.

107. C — When a cost-saving conflicts with public safety, the engineer must place public safety first, since it is the paramount ethical duty. No economic benefit justifies compromising the safety of those affected.

108. B — Accepting a substantial gift from a supplier bidding on a contract creates a conflict of interest that could bias the engineer's judgement, and must be avoided. Such gifts compromise impartial decision-making.

109. C — An engineer must state qualifications truthfully and without exaggeration, since misrepresenting competence can lead to unsafe work being undertaken. Honesty in credentials protects the public and the profession.

110. D — On discovering an illegal discharge, the engineer should report it through the appropriate channels, fulfilling the duty to protect public health and the environment. Concealing or delaying would breach professional and legal obligations.