PRACTICE EXAM 16: FE CHEMICAL SIMULATION (110 QUESTIONS)

Mathematics

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

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

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

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

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

2. Evaluate the definite integral of x^2 from $x = 0$ to $x = 2$.

A. 2.67

B. 4

C. 8

D. 1.33

3. A square matrix is singular when its determinant equals:

A. One

B. Zero

C. A positive value

D. A negative value

4. What is the derivative of sin(x) with respect to x?

A. $\cos(x)$

B. $-\cos(x)$

C. $-\sin(x)$

D. $\tan(x)$

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

A. 0

B. Infinity

C. 3

D. 2

6. Two vectors at right angles have magnitudes 3 and 4. What is the magnitude of their resultant?

A. 5

B. 7

C. 1

D. 12

Probability and Statistics

7. Two independent events have probabilities 0.6 and 0.5. What is the probability that both occur?

A. 0.30

B. 1.1

C. 0.55

D. 0.10

8. What is the median of the data set 2, 7, 9, 4, and 11?

A. 9

B. 7

C. 6.6

D. 4

9. In how many ordered ways can 2 items be selected from 6 distinct items?

A. 12

B. 15

C. 30

D. 720

10. The standard error of the mean decreases as the:

A. Sample size increases

B. Variance increases

C. Mean increases

D. Range increases

11. For a Poisson process with mean 3, what is the probability of observing zero events ($e^{-3} = 0.050$)?

A. 0.30

B. 0.15

C. 0.050

D. 0.95

Engineering Sciences

12. What is the impulse delivered by a 20 N force acting for 3 seconds?

A. 6.7 N·s

B. 23 N·s

C. 17 N·s

D. 60 N·s

13. Three resistors of 5 Ω, 7 Ω, and 8 Ω are connected in series. What is the total resistance?

A. 20 Ω

B. 2.0 Ω

C. 280 Ω

D. 10 Ω

14. A 2 kg object moves at 6 m/s. What is its kinetic energy?

A. 12 J

B. 36 J

C. 72 J

D. 6 J

15. A current of 4 A flows through a 5 Ω resistor. What is the voltage across it?

A. 0.8 V

B. 1.25 V

C. 20 V

D. 9 V

Materials Science

16. The property that allows a metal to be drawn into a wire is its:

A. Hardness

B. Ductility

C. Brittleness

D. Conductivity

17. Engineering strain is defined as the:

A. Change in length divided by the original length

B. Force divided by the cross-sectional area

C. Stress multiplied by the area

D. Energy stored per unit volume

18. Adding chromium to steel chiefly improves:

A. Its density

B. Its colour

C. Its corrosion resistance

D. Its electrical conductivity

19. Creep is the slow, time-dependent deformation of a material under:

A. A rapidly cycling load

B. A constant sustained stress at elevated temperature

C. Zero applied stress

D. Compressive impact alone

20. Doping a semiconductor with impurity atoms:

A. Increases its electrical conductivity

B. Makes it a perfect insulator

C. Removes all charge carriers

D. Converts it into a metal

Chemistry and Biology

21. An aqueous solution has a hydroxide concentration of 1×10^{-2} mol/L. What is its pH?

A. 12

B. 2

C. 7

D. 1×10^{-2}

22. What is the molar mass of ethane, C_2H_6?

A. 16 g/mol

B. 28 g/mol

C. 30 g/mol

D. 44 g/mol

23. A fixed quantity of gas occupies 2 L at 300 K. At constant pressure, what volume does it occupy at 450 K?

A. 1 L

B. 4 L

C. 1.33 L

D. 3 L

24. Adding an inert gas at constant volume to a gaseous equilibrium:

A. Shifts it toward the products

B. Shifts it toward the reactants

C. Stops the reaction

D. Causes no shift

25. The decomposition $2H_2O_2 \rightarrow 2H_2O + O_2$ goes to completion. How many moles of oxygen form from 4 mol of hydrogen peroxide?

A. 4 mol

B. 8 mol

C. 2 mol

D. 1 mol

26. In water, hydrogen has an oxidation state of +1, so oxygen has an oxidation state of:

A. −1

B. −2

C. 0

D. +2

27. A strong acid is one that:

A. Has a high boiling point

B. Is highly concentrated

C. Fully dissociates in water

D. Neutralises slowly

28. In a eukaryotic cell, aerobic respiration occurs chiefly in the:

A. Nucleus

B. Ribosome

C. Mitochondrion

D. Cell wall

Fluid Mechanics

29. A fluid (density 1000 kg/m^3, viscosity 2×10^{-4} Pa·s) flows at 0.8 m/s through a 0.025 m pipe. What is the Reynolds number?

A. 100000

B. 10000

C. 1000

D. 4000

30. Flow at 6 m/s in a 0.05 m^2 duct enters a 0.01 m^2 section. What is the velocity in the smaller section?

A. 1.2 m/s

B. 6 m/s

C. 12 m/s

D. 30 m/s

31. Bernoulli's equation sums the pressure head, the velocity head, and the:

A. Friction head

B. Pump head

C. Elevation head

D. Thermal head

32. What is the hydrostatic pressure at a depth of 10 m in water (density 1000 kg/m^3)?

A. 10 kPa

B. 981 kPa

C. 9.81 kPa

D. 98.1 kPa

33. For laminar pipe flow at a Reynolds number of 128, what is the Darcy friction factor?

A. 64

B. 5.0

C. 0.05

D. 0.5

34. A pump delivers 0.02 m^3/s of water against a head of 25 m. What is the ideal hydraulic power?

A. 0.49 kW

B. 49 kW

C. 4.91 kW

D. 491 W

35. A flow of 0.5 m^3/s passes through a duct of cross-sectional area 0.1 m^2. What is the velocity?

A. 0.2 m/s

B. 0.05 m/s

C. 50 m/s

D. 5 m/s

36. Using the Darcy equation with $f = 0.04$, $L = 60$ m, $D = 0.06$ m, and $v = 2$ m/s, what is the head loss?

A. 2.04 m

B. 4.08 m

C. 1.02 m

D. 8.16 m

37. Turbulent flow is characterised by:

A. Chaotic eddies and mixing

B. Smooth parallel layers

C. A zero velocity gradient

D. No shear stress

Thermodynamics

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

A. 25%

B. 50%

C. 75%

D. 40%

39. Five moles of an ideal gas (Cp = 29 J/mol·K) are heated by 10 K at constant pressure. What is the enthalpy change?

A. 725 J

B. 1450 J

C. 2900 J

D. 290 J

40. A closed system absorbs 500 J of heat while doing 200 J of work. What is the change in internal energy?

A. 300 J

B. 700 J

C. −300 J

D. 500 J

41. Steam enters an adiabatic turbine at 3100 kJ/kg and leaves at 2700 kJ/kg, flowing at 8 kg/s. What is the shaft power?

A. 400 kW

B. 800 kW

C. 1600 kW

D. 3200 kW

42. A Carnot heat pump operates between 280 K and 320 K. What is its heating coefficient of performance, T_h/(T_h − T_c)?

A. 7

B. 9

C. 8

D. 0.125

43. An equimolar liquid mixture of A (pure vapour pressure 180 kPa) and B (20 kPa) follows Raoult's law. What is the bubble-point pressure?

A. 20 kPa

B. 100 kPa

C. 180 kPa

D. 200 kPa

44. For an ideal gas, the constant-pressure heat capacity Cp is always:

A. Greater than Cv

B. Less than Cv

C. Equal to Cv

D. Zero

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

A. Isochoric

B. Isobaric

C. Isothermal

D. Adiabatic

46. The heat absorbed when a liquid vaporises at constant temperature is the:

A. Sensible heat

B. Latent heat of vaporisation

C. Specific heat

D. Heat of reaction

Material and Energy Balances

47. A 900 kg/h feed is separated into a 300 kg/h distillate and a bottoms stream. What is the bottoms flow rate?

A. 1200 kg/h

B. 300 kg/h

C. 600 kg/h

D. 900 kg/h

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

A. 500 kg/h

B. 120 kg/h

C. 1380 kg/h

D. 1000 kg/h

49. Complete combustion of propane follows $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$. How many moles of oxygen are needed for 2 mol of propane?

A. 5 mol

B. 6 mol

C. 10 mol

D. 15 mol

50. A 250 kg stream of 12% salt is mixed with a 250 kg stream of 28% salt. What is the salt content of the mixture?

A. 20%

B. 40%

C. 28%

D. 12%

51. A reactor is fed 1000 mol of A, of which 250 mol leaves unreacted. What is the conversion?

A. 25%

B. 75%

C. 100%

D. 250 mol

52. A process recycles 1000 mol/h and receives a fresh feed of 250 mol/h. What is the recycle ratio?

A. 0.25

B. 1

C. 4

D. 1250

53. How much heat is required to raise 20 kg of water by 40 °C, with a specific heat of 4.18 kJ/kg·K?

A. 836 kJ

B. 3344 kJ

C. 1672 kJ

D. 6688 kJ

54. A solid has a moisture content of 30% on a wet basis. What is the equivalent moisture content on a dry basis?

A. 30%

B. 42.9%

C. 23.1%

D. 70%

55. In the reaction 3A → 4B, 6 mol of A reacts completely. How many moles of B are formed?

A. 6 mol

B. 4.5 mol

C. 8 mol

D. 18 mol

56. A burner needs 20 mol of oxygen stoichiometrically but is supplied with 25 mol. What is the percentage excess oxygen?

A. 20%

B. 80%

C. 25%

D. 125%

57. For the adiabatic mixing of two streams, the energy balance requires that the inlet enthalpy equals:

A. Zero

B. The outlet enthalpy

C. Twice the inlet value

D. The work done

Heat Transfer

58. A 0.1 m thick wall (k = 0.8 W/m·K, area 2.5 m^2) has a 60 °C temperature difference across it. What is the conductive heat rate?

A. 600 W

B. 1200 W

C. 2400 W

D. 300 W

59. A 3 m^2 surface transfers heat by convection with h = 40 W/m^2·K and a temperature difference of 25 °C. What is the heat rate?

A. 3000 W

B. 1500 W

C. 6000 W

D. 750 W

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

A. 81×

B. 27×

C. 9×

D. 3×

61. In a counter-current exchanger, the hot stream cools from 80 °C to 50 °C while the cold stream warms from 20 °C to 40 °C. What is the log-mean temperature difference?

A. 40 °C

B. 35 °C

C. 30 °C

D. 34.8 °C

62. Two wall layers have thermal resistances of 0.6 K/W and 0.9 K/W in series. What is the total resistance?

A. 0.36 K/W

B. 0.75 K/W

C. 1.5 K/W

D. 0.3 K/W

63. Two convective films, each 500 $W/m^2 \cdot K$, act in series with negligible wall resistance. What is the overall coefficient U?

A. 1000 $W/m^2 \cdot K$

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

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

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

64. An exchanger has $U = 250\ W/m^2 \cdot K$, area 8 m^2, and a log-mean temperature difference of 30 °C. What is the heat duty?

A. 6 kW

B. 18 kW

C. 30 kW

D. 60 kW

65. In steady-state conduction through a uniform plane wall, the temperature profile is:

A. Linear

B. Parabolic

C. Exponential

D. Sinusoidal

66. The radiation view factor accounts for the fraction of radiation leaving one surface that:

A. Is absorbed by the gas

B. Is reflected back

C. Is converted to conduction

D. Reaches another surface

Mass Transfer and Separation

67. A species diffuses through a 2 mm film with $D = 6 \times 10^{-9}$ m²/s and a concentration difference of 10 mol/m³. What is the molar flux?

A. 6×10^{-5} mol/m²·s

B. 1.2×10^{-5} mol/m²·s

C. 6×10^{-8} mol/m²·s

D. 3×10^{-5} mol/m²·s

68. For a relative volatility of 3, what vapour composition is in equilibrium with a liquid of mole fraction 0.4?

A. 0.40

B. 0.67

C. 0.50

D. 0.80

69. The McCabe–Thiele method graphically determines the number of:

A. Reactors needed

B. Pumps required

C. Heat exchangers

D. Theoretical stages in a binary distillation

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. 0.67

C. 0.75

D. 0.80

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. 2.3

B. 10

C. 0.90

D. 4.6

72. An absorption factor $A = L/(mV)$ greater than one favours:

A. Stripping

B. Flooding

C. No transfer

D. Efficient absorption

73. Knudsen diffusion becomes important when:

A. The gas is at high pressure

B. The pores are very large

C. The temperature is very low

D. The pore size is comparable to the molecular mean free path

74. The reboiler at the base of a distillation column provides the:

A. Reflux liquid

B. Feed preheat

C. Vapour flow up the column

D. Cooling duty

75. Ultrafiltration separates dissolved species primarily by:

A. Charge attraction

B. Molecular size exclusion

C. Boiling point difference

D. Magnetic force

Solids Handling

76. A 50 μm particle ($\Delta\rho = 2000\ kg/m^3$) settles in a fluid of viscosity 1×10^{-3} Pa·s. What is its Stokes' law terminal velocity?

A. 5.4×10^{-3} m/s

B. 1.1×10^{-2} m/s

C. 6.8×10^{-4} m/s

D. 2.73×10^{-3} m/s

77. A sieve analysis reports the mass fraction of particles falling within each:

A. Density class

B. Size range

C. Colour band

D. Moisture level

78. Segregation of a powder mixture during handling is promoted by:

A. Identical particle sizes

B. High cohesion among the particles

C. Differences in particle size and density

D. A uniform spherical shape

79. For transporting a fine powder over a long distance within an enclosed line, the suitable method is:

A. An open belt conveyor

B. Pneumatic conveying

C. A wheelbarrow

D. A gravity chute alone

Chemical Reaction Engineering

80. A first-order reaction ($k = 0.1$ min^{-1}) starts at 6 mol/L. What is the concentration after 10 minutes, using $C = C_0e$^(−kt)?

A. 3.0 mol/L

B. 2.21 mol/L

C. 0.6 mol/L

D. 0.37 mol/L

81. A first-order reaction ($k = 0.2\ min^{-1}$) runs in a PFR with a space time of 5 minutes. What conversion is achieved, using $X = 1 - e^{(-k\tau)}$?

A. 0.50

B. 0.86

C. 0.63

D. 0.95

82. A first-order reaction ($k = 0.25\ min^{-1}$) reaches 50% conversion in a CSTR. What space time is required?

A. 1 min

B. 2 min

C. 8 min

D. 4 min

83. A zero-order reaction has k = 2 mol/L·min and an initial concentration of 8 mol/L. What is its half-life, $t_{1/2} = C_0/(2k)$?

A. 4 min

B. 8 min

C. 1 min

D. 2 min

84. For the reversible reaction A ⇌ B, the forward rate constant is 18 and the reverse is 6. What is the equilibrium constant?

A. 12

B. 24

C. 3

D. 0.33

85. For positive-order kinetics at the same conversion, a CSTR requires:

A. A larger volume than a PFR

B. A smaller volume than a PFR

C. The same volume as a PFR

D. No reactor volume

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

A. Fastest step

B. First step always

C. Last step always

D. Slowest (rate-determining) step

Engineering Economics

87. What is the future worth of $12,000 invested for 5 years at 4% interest ($1.04^5 = 1.2167$)?

A. $14,600

B. $14,400

C. $15,600

D. $13,200

88. What is the present worth of $50,000 to be received in 6 years at 10% interest ($1.10^6 = 1.7716$)?

A. $35,000

B. $45,455

C. $28,224

D. $50,000

89. A $150,000 asset with a $30,000 salvage value is depreciated straight-line over 10 years. What is the annual depreciation?

A. $15,000

B. $13,500

C. $120,000

D. $12,000

90. What is the capitalised cost of a perpetual annual expense of $12,000 at an interest rate of 6%, using $P = A/i$?

A. $72,000

B. $720

C. $12,720

D. $200,000

Process Design

91. A piping and instrumentation diagram adds detail not shown on a process flow diagram, namely:

A. Only the major vessels

B. All instruments, valves, and control loops

C. The plant economics

D. The marketing plan

92. The optimum feed location in a distillation column is:

A. Always the top stage

B. At the stage matching the feed composition

C. Always the bottom stage

D. Outside the column

93. Equipment that cost $100,000 at a cost index of 400 is re-estimated at a current index of 600. What is the updated cost?

A. $150,000

B. $66,667

C. $100,000

D. $200,000

94. For a vessel handling dilute sulphuric acid at moderate temperature, a suitable material choice is:

A. Plain carbon steel

B. Untreated aluminium

C. A suitable stainless steel or lined vessel

D. Ordinary cast iron

95. A positive-displacement pump is preferred when:

A. A precise, constant flow against high pressure is needed

B. Very high flow at low head is required

C. The liquid contains large solids

D. No metering accuracy matters

96. A reboiler in a distillation column is best supplied by:

A. Cooling water

B. A hot utility such as steam

C. A refrigerant

D. Ambient air alone

97. A blowdown drum is provided in order to:

A. Store product permanently

B. Heat the feed

C. Measure flow rate

D. Safely collect and depressurise relieved liquids and vapours

Process Control

98. A purely proportional controller characteristically leaves a:

A. Zero error

B. Sustained oscillation

C. Integral windup

D. Steady-state offset

99. A Coriolis meter measures mass flow rate directly by detecting:

A. The fluid colour

B. The twisting of a vibrating tube

C. The static pressure

D. The temperature rise

100. If a process variable rises above set point and the valve must close to correct it, the controller action is:

A. On–off only

B. Feedforward

C. Reverse acting

D. Derivative only

101. A long process dead time makes control more difficult because it:

A. Delays the effect of corrective action

B. Eliminates all disturbances

C. Removes the need for tuning

D. Increases the gain margin

Safety, Health, and Environment

102. Besides fuel, oxygen, an ignition source, and dispersion, a dust explosion also requires:

A. High humidity

B. A low temperature

C. An inert gas

D. Confinement

103. The IDLH concentration of a substance is the level that is:

A. Always safe for 8 hours

B. Detectable only by instruments

C. Immediately dangerous to life or health

D. The legal disposal limit

104. A risk matrix ranks hazards by combining:

A. Likelihood and severity

B. Cost and schedule

C. Colour and shape

D. Age and size

105. Local exhaust ventilation controls a contaminant by:

A. Slowly diluting the whole room

B. Capturing it at the source

C. Heating the air

D. Recirculating contaminated air

106. Greenhouse gas emissions from a combustion process are dominated by:

A. Carbon dioxide

B. Nitrogen

C. Argon

D. Water vapour alone

Ethics and Professional Practice

107. An engineer should sign and seal only documents that:

A. Any colleague requests

B. Appear technically reasonable

C. Were prepared by or under their direct supervision

D. Carry the company logo

108. Offering a payment to a public official to secure a permit is:

A. Acceptable if the amount is small

B. Bribery and strictly prohibited

C. A standard cost of business

D. Required to save time

109. If an engineer's earlier design is later found to be unsafe, the proper response is to:

A. Ignore it once it was handed over

B. Notify the responsible parties promptly

C. Wait for a lawsuit to be filed

D. Blame the contractor

110. When presenting technical findings publicly, an engineer must clearly distinguish:

A. Fact from professional opinion

B. Friends from competitors

C. Profit from loss

D. Nothing in particular

Practice Exam 16 — Answer Key and Explanations

1. C — The characteristic equation $(r + 2)^2 = 0$ gives a repeated root $r = -2$, so the solution is $(C_1 + C_2x)e^{(-2x)}$. A repeated root requires the extra factor of x in the second term.

2. A — The antiderivative of x^2 is $x^3/3$, evaluated from 0 to 2 as $8/3 \approx 2.67$. Definite integration accumulates the area under the curve.

3. B — A square matrix is singular when its determinant is zero, meaning it has no inverse. A zero determinant indicates linearly dependent rows or columns.

4. A — The derivative of sin(x) is cos(x). This standard result is fundamental to analysing oscillatory and periodic behaviour.

5. C — As $x \to \infty$ the ratio is dominated by the leading terms, giving $3x^2/x^2 = 3$. Only the highest-power terms matter in the limit at infinity.

6. A — For perpendicular vectors the resultant is $\sqrt{(3^2 + 4^2)} = \sqrt{25} = 5$. The Pythagorean relation applies because the components are at right angles.

7. A — For independent events, the joint probability is the product, $0.6 \times 0.5 = 0.30$. Multiplying applies when one event does not affect the other.

8. B — Sorting the data gives 2, 4, 7, 9, 11, with the middle value 7 as the median. The median is the central value of the ordered set.

9. C — The ordered selection count is $P(6,2) = 6 \times 5 = 30$. Permutations count arrangements where order matters.

10. A — The standard error of the mean is $\sigma/\sqrt{n}$, so it decreases as the sample size n increases. Larger samples give more precise estimates of the mean.

11. C — The Poisson probability of zero events is $e^{(-\lambda)} = e^{(-3)} = 0.050$. With mean 3, observing none is unlikely.

12. D — Impulse is force times time, $20 \times 3 = 60$ N·s. Impulse equals the change in momentum it produces.

13. A — Series resistances add directly, $5 + 7 + 8 = 20\ \Omega$. The series total always exceeds any single resistor.

14. B — Kinetic energy is $\frac{1}{2}mv^2 = \frac{1}{2} \times 2 \times 6^2 = 36$ J. The square dependence on velocity makes speed the dominant factor.

15. C — Ohm's law gives $V = IR = 4 \times 5 = 20$ V. Voltage is proportional to both current and resistance.

16. B — Ductility is the property that allows a metal to be drawn into a wire, undergoing large plastic deformation without fracture. It distinguishes formable metals from brittle materials.

17. A — Engineering strain is the change in length divided by the original length, a dimensionless ratio. It measures the relative deformation under load.

18. C — Adding chromium to steel forms a passive oxide layer that greatly improves corrosion resistance, producing stainless steel. At least about 10.5% chromium is needed for this effect.

19. B — Creep is the slow, time-dependent deformation that occurs under a constant sustained stress at elevated temperature. It governs the life of components such as turbine blades and boiler tubes.

20. A — Doping introduces charge carriers that increase a semiconductor's electrical conductivity in a controlled way. This tailored conductivity is the basis of all semiconductor devices.

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

22. C — Summing atomic masses, 2C (24) + 6H (6) = 30 g/mol. Molar mass converts between mass and moles in stoichiometry.

23. D — By Charles's law at constant pressure, volume is proportional to absolute temperature, so $V_2 = 2 \times (450/300) = 3$ L. Heating the gas expands it in proportion to its absolute temperature.

24. D — Adding an inert gas at constant volume does not change the partial pressures or concentrations of the reacting species, so the equilibrium does not shift. Only changes affecting the reactive components move the equilibrium.

25. C — The two-to-one stoichiometry gives one mole of oxygen per two of hydrogen peroxide, so 4 mol of H_2O_2 yields 2 mol of O_2. The decomposition conserves the oxygen atoms.

26. B — Since the two hydrogens contribute +2 and the molecule is neutral, oxygen must be −2. This is the usual oxidation state of oxygen in its compounds.

27. C — A strong acid fully dissociates in water, releasing all its hydrogen ions, regardless of concentration. This complete ionisation, not concentration, defines acid strength.

28. C — Aerobic respiration in a eukaryotic cell occurs chiefly in the mitochondrion, where the electron transport chain produces most of the cell's ATP. The mitochondrion is aptly termed the cell's powerhouse.

29. A — Reynolds number is $\rho vD/\mu = (1000 \times 0.8 \times 0.025)/(2 \times 10^{-4}) = 100{,}000$. This strongly turbulent value sets the appropriate friction correlation.

30. D — Continuity gives $v_2 = v_1A_1/A_2$ = 6 × (0.05/0.01) = 30 m/s. The fivefold area reduction raises the velocity fivefold.

31. C — Bernoulli's equation sums the pressure head, the velocity head, and the elevation head, all conserved along a streamline. Together they represent the total mechanical energy per unit weight.

32. D — Hydrostatic pressure is ρgh = 1000 × 9.81 × 10 = 98,100 Pa ≈ 98.1 kPa. Pressure rises linearly with depth.

33. D — For laminar flow, the friction factor is 64/Re = 64/128 = 0.5. The inverse dependence on Reynolds number gives high friction at low flow.

34. C — Ideal hydraulic power is ρgQH = 1000 × 9.81 × 0.02 × 25 = 4905 W ≈ 4.91 kW. Dividing by efficiency would give the shaft power.

35. D — Velocity is flow over area, 0.5/0.1 = 5 m/s. This follows directly from the continuity equation.

36. D — The Darcy equation gives $h_f = f(L/D)(v^2/2g)$ = 0.04 × (60/0.06) × (4/19.62) = 8.16 m. Friction head loss scales with the square of velocity.

37. A — Turbulent flow is characterised by chaotic eddies and intense mixing across the flow. This contrasts with the orderly layered motion of laminar flow.

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

39. B — Enthalpy change at constant pressure is $nC_p\Delta T$ = 5 × 29 × 10 = 1450 J. The constant-pressure heat capacity accounts for the expansion work.

40. A — The first law gives $\Delta U = Q - W$ = 500 − 200 = 300 J. Heat added that is not spent on work raises the internal energy.

41. D — Adiabatic turbine power is $\dot{m}(h_1 - h_2)$ = 8 × (3100 − 2700) = 3200 kW. The enthalpy drop converts directly into shaft work.

42. C — The heating coefficient of performance is $T_h/(T_h - T_c)$ = 320/40 = 8. The small temperature lift gives a high COP.

43. B — Raoult's law gives the bubble pressure as 0.5 × 180 + 0.5 × 20 = 100 kPa. The total pressure is the mole-fraction-weighted sum of the pure vapour pressures.

44. A — For an ideal gas, C_p always exceeds C_v by the gas constant R, because constant-pressure heating also does expansion work. This extra work demands more heat for the same temperature rise.

45. A — A process carried out at constant volume is isochoric, as distinct from isobaric, isothermal, or adiabatic. No expansion work is done in an isochoric process.

46. B — The latent heat of vaporisation is the heat absorbed as a liquid vaporises at constant temperature, with no change in temperature. It supplies the energy to overcome intermolecular forces during the phase change.

47. C — A steady-state mass balance gives the bottoms as 900 − 300 = 600 kg/h. Conservation of mass closes the separation.

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

49. C — At 5 mol of oxygen per mole of propane, 2 mol of propane needs 2 × 5 = 10 mol. Combustion stoichiometry sets the oxygen demand.

50. A — The combined salt is 0.12 × 250 + 0.28 × 250 = 30 + 70 = 100 kg in 500 kg, giving 20%. A component balance yields the blended composition.

51. B — Conversion is (1000 − 250)/1000 = 75%. This fraction measures how completely the feed is consumed.

52. C — The recycle ratio is recycle over fresh feed, 1000/250 = 4. It characterises the process's reliance on recycling.

53. B — Sensible heat is $mC_p\Delta T$ = 20 × 4.18 × 40 = 3344 kJ. This relation sizes the heating duty for a temperature change.

54. B — Converting 30% wet basis gives dry basis = 30/(100 − 30) = 42.9%. The dry basis exceeds the wet basis because its denominator excludes the water.

55. C — The stoichiometry produces four moles of B per three of A, so 6 mol of A yields 8 mol of B. Reaction stoichiometry converts reactant consumed into product formed.

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

57. B — For adiabatic mixing with no heat loss or work, the energy balance requires the total inlet enthalpy to equal the total outlet enthalpy. The combined stream carries away exactly the energy the feeds brought in.

58. B — Fourier's law gives $Q = kA\Delta T/L$ = (0.8 × 2.5 × 60)/0.1 = 1200 W. Conductive heat rate scales with conductivity, area, and driving temperature.

59. A — Convective heat rate is $hA\Delta T$ = 40 × 3 × 25 = 3000 W. The coefficient h reflects how effectively the fluid removes heat.

60. A — Emissive power scales with the fourth power of absolute temperature, so tripling T raises it by 3^4 = 81 times. This steep dependence makes radiation dominant at high temperatures.

61. D — With $\Delta T_1 = 80 - 40 = 40$ °C and $\Delta T_2 = 50 - 20 = 30$ °C, the log-mean is $(40 - 30)/\ln(40/30) = 34.8$ °C. The LMTD is the correct mean driving force, below the arithmetic mean of 35 °C.

62. C — Series thermal resistances add directly, 0.6 + 0.9 = 1.5 K/W. The thermal-circuit analogy makes composite-wall analysis straightforward.

63. D — With negligible wall resistance, $1/U = 1/500 + 1/500 = 0.004$, so $U = 250$ W/m²·K. Two equal series films halve the overall coefficient.

64. D — Exchanger duty is $UA\Delta T = 250 \times 8 \times 30 = 60{,}000$ W = 60 kW. This product of coefficient, area, and driving force sizes the exchanger.

65. A — In steady conduction through a uniform plane wall, the temperature falls linearly across the thickness, since the heat flux is constant. A constant flux through constant area and conductivity gives a straight-line profile.

66. D — The view factor is the fraction of radiation leaving one surface that reaches another, set purely by the geometry. It quantifies how the surfaces "see" each other for radiative exchange.

67. D — Fick's law gives flux = $D \cdot \Delta C/\delta = (6 \times 10^{-9} \times 10)/(2 \times 10^{-3}) = 3 \times 10^{-5}$ mol/m²·s. Flux rises with diffusivity and concentration difference and falls with film thickness.

68. B — Using $y = \alpha x/[1 + (\alpha - 1)x] = (3 \times 0.4)/(1 + 2 \times 0.4) = 1.2/1.8 = 0.67$. The vapour is enriched in the volatile component relative to the liquid.

69. D — The McCabe–Thiele method graphically steps off the number of theoretical stages in a binary distillation between the operating and equilibrium lines. It is a classic design tool for two-component columns.

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

71. A — The number of transfer units is $\ln(C_{in}/C_{out}) = \ln(10) \approx 2.3$. NTU rises with the fractional removal demanded.

72. D — An absorption factor $A = L/(mV)$ greater than one means the liquid capacity exceeds what the vapour delivers, favouring efficient absorption. A value below one instead favours stripping.

73. D — Knudsen diffusion dominates when the pore size is comparable to or smaller than the molecular mean free path, so molecules collide with the walls more than with each other. It governs transport in fine catalyst pores at low pressure.

74. C — The reboiler boils liquid at the column base to generate the vapour that rises up the column. This vapour flow is essential for the counter-current contacting that achieves separation.

75. B — Ultrafiltration separates primarily by molecular size exclusion, retaining macromolecules and colloids while passing smaller species. The membrane pore size sets the cut-off.

76. D — Stokes' law gives $v = gd^2\Delta\rho/(18\mu) = (9.81 \times (5 \times 10^{-5})^2 \times 2000)/(18 \times 10^{-3}) = 2.73 \times 10^{-3}$ m/s. The square dependence on diameter makes settling highly size-sensitive.

77. B — A sieve analysis reports the mass fraction of particles retained within each size range between successive screens. This builds up the particle-size distribution of the sample.

78. C — Segregation during handling is promoted by differences in particle size and density, which let components separate as they flow or vibrate. Uniform, cohesive powders resist this de-mixing.

79. B — Pneumatic conveying transports fine powder over long distances within an enclosed pipeline using a moving gas stream. Its dust-free containment suits fine, hazardous, or valuable powders.

80. B — First-order decay gives $C = C_0e^{(-kt)} = 6 \times e^{(-0.1 \times 10)} = 6 \times e^{(-1)} = 6 \times 0.368 = 2.21$ mol/L. The concentration falls exponentially at a rate fixed by k.

81. C — For a first-order PFR, conversion is $X = 1 - e^{(-k\tau)} = 1 - e^{(-0.2 \times 5)} = 1 - e^{(-1)} = 0.63$. The plug-flow reactor reaches this conversion at a space time of one time constant.

82. D — For a first-order CSTR, $\tau = X/[k(1 - X)] = 0.5/(0.25 \times 0.5) = 4$ min. The space time links reactor size to the conversion achieved.

83. D — The zero-order half-life is $C_0/(2k) = 8/(2 \times 2) = 2$ min. Unlike first-order, the zero-order half-life depends on the starting concentration.

84. C — At equilibrium the forward and reverse rates balance, so $K = k_{forward}/k_{reverse} = 18/6 = 3$. This links the kinetic constants to the equilibrium position.

85. A — For positive-order kinetics at the same conversion, a CSTR requires a larger volume than a PFR, because it operates entirely at the low exit concentration. The PFR's higher average concentration makes it more volume-efficient.

86. D — In a multi-step reaction, the overall rate is set by the slowest, rate-determining step, which acts as the bottleneck. Speeding up the faster steps does not increase the overall rate.

87. A — Future worth is $P(1 + i)^n = 12{,}000 \times 1.04^5 = 12{,}000 \times 1.2167 = \$14{,}600$. Compounding grows the sum forward at the stated rate.

88. C — Present worth is $F/(1 + i)^n = 50{,}000/1.10^6 = 50{,}000/1.7716 = \$28{,}224$. Discounting reflects that a future sum is worth less today.

89. D — Straight-line depreciation is (150,000 − 30,000)/10 = $12,000 per year. This even allocation spreads the depreciable basis across the service life.

90. D — Capitalised cost of a perpetual annual amount is A/i = 12,000/0.06 = $200,000. This perpetuity formula values an endless stream of equal payments as a single sum.

91. B — A piping and instrumentation diagram adds the full detail of instruments, valves, and control loops that a process flow diagram omits. It is the definitive reference for construction and control design.

92. B — The optimum feed stage is the one whose composition matches the feed, minimising the mixing of streams of different composition. Feeding elsewhere increases the separation work required.

93. A — Updating with the cost index gives 100,000 × (600/400) = $150,000. The index ratio corrects the historical cost for inflation.

94. C — Dilute sulphuric acid at moderate temperature calls for a suitable stainless steel or a lined vessel, since carbon steel and common metals corrode. Correct material choice prevents corrosion failure and contamination.

95. A — A positive-displacement pump delivers a precise, near-constant flow against high pressure, since each stroke moves a fixed volume. This makes it ideal for metering and high-head duties.

96. B — A reboiler supplies heat to boil the column bottoms, so it is served by a hot utility such as steam. The steam condenses to release its latent heat to the process liquid.

97. D — A blowdown drum safely collects and depressurises the liquids and vapours discharged from relief devices before further handling. It separates phases and protects downstream equipment and the flare.

98. D — A purely proportional controller leaves a steady-state offset, because some error is needed to sustain the corrective output. Integral action is added to remove this residual offset.

99. B — A Coriolis meter measures mass flow directly by sensing the twisting of a vibrating tube caused by the flowing fluid. This gives an accurate, fluid-property-independent mass-flow reading.

100. C — When the controlled variable rises and the valve must close to correct it, the controller is reverse acting, moving its output opposite to the measurement. The correct action sense is essential for stable control.

101. A — A long dead time delays the effect of corrective action, so the controller acts on outdated information and may overcorrect. This makes loops with large dead time inherently harder to control.

102. D — Beyond fuel, oxygen, ignition, and dust dispersion, a dust explosion also requires confinement, which allows the pressure to build. This fifth element distinguishes a dust explosion's "pentagon" from the fire triangle.

103. C — The IDLH concentration is the level immediately dangerous to life or health, from which a worker could not escape without impairment. It defines the threshold requiring the highest level of respiratory protection.

104. A — A risk matrix ranks hazards by combining the likelihood of an event with the severity of its consequences. This two-dimensional ranking helps prioritise which risks to address first.

105. B — Local exhaust ventilation captures a contaminant at its source before it disperses into the workplace air. Capturing at the source is far more effective than diluting the whole room.

106. A — Carbon dioxide is the dominant greenhouse gas emitted by a combustion process, formed from the carbon in the fuel. Reducing CO_2 emissions is central to limiting a process's climate impact.

107. C — An engineer must sign and seal only documents prepared by or under their direct supervision, certifying personal responsibility for the work. Sealing unfamiliar work misrepresents accountability and endangers the public.

108. B — Offering a payment to a public official to secure a permit is bribery, which is unethical and illegal regardless of the amount. Such conduct corrupts the regulatory process and is strictly prohibited.

109. B — On learning that an earlier design is unsafe, the engineer must promptly notify the responsible parties so the danger can be addressed. The duty to protect the public continues after the project is handed over.

110. A — When presenting findings publicly, an engineer must clearly distinguish established fact from personal professional opinion. This honesty prevents the audience from mistaking judgement for proven data.