PRACTICE EXAM 19 : FE CIVIL SIMULATION (110 QUESTIONS)

110 questions. Recommended time: 5 hours 20 minutes.

1. A simply supported beam of span 6 m carries a uniform load of 8 kN/m plus a central point load of 20 kN. What is the maximum bending moment at midspan?

A. 36 kN·m

B. 66 kN·m

C. 30 kN·m

D. 96 kN·m

2. A pump must deliver 0.08 m³/s against a total head of 40 m at 75% efficiency. Using $P = \gamma QH/\eta$, what shaft power is required?

A. 23.5 kW

B. 31.4 kW

C. 3.14 kW

D. 41.9 kW

3. Machine A costs $50,000 plus $5,000/yr; Machine B costs $30,000 plus $9,000/yr. Over a 5-year life at 0% interest, the correct conclusion is:

A. The two machines have equal total cost

B. Machine A is always cheaper

C. Machine B is always cheaper

D. Neither can be compared

4. A venturi meter has an inlet area of 0.02 m^2 and a throat area of 0.01 m^2. With an inlet velocity of 2 m/s, what is the throat velocity?

A. 4 m/s

B. 1 m/s

C. 2 m/s

D. 8 m/s

5. A crest vertical curve with grades +3% and −3% (A = 6) must provide 200 m of stopping sight distance. Using $L = AS^2/658$ (S < L), what is the required curve length?

A. 60.8 m

B. 121.6 m

C. 182 m

D. 364.7 m

6. A 5 m doubly drained clay layer has $c_v = 2\ m^2/yr$. Using $T_v = 0.197$ for 50% consolidation and $t = T_v \cdot H^2/c_v$, how long until 50% consolidation?

A. 2.46 yr

B. 0.31 yr

C. 0.62 yr

D. 1.23 yr

7. A frame has a pin at A (two reaction components) and a roller at B (one). With three equilibrium equations, the frame is:

A. Indeterminate to the first degree

B. Statically determinate

C. Unstable

D. Indeterminate to the third degree

8. An engineer signs and seals a report containing data they know to be falsified by another party. This action is:

A. Acceptable if the other party is responsible

B. Acceptable with a verbal disclaimer

C. A serious ethics violation regardless of who falsified the data

D. Required to maintain the client relationship

9. Water flows through a 0.15 m diameter pipe at 3 m/s. What is the flow rate?

A. 0.34 m^3/s

B. 0.45 m^3/s

C. 0.018 m^3/s

D. 0.053 m^3/s

10. What are the eigenvalues of the diagonal matrix with entries 2 and 3 on its diagonal?

A. 2 and 3

B. 0 and 0

C. 5 and 6

D. 6 and 1

11. A 1,200 kg car accelerates from rest to 24 m/s in 12 s. What is its average power output?

A. 28.8 kW

B. 14.4 kW

C. 57.6 kW

D. 2.4 kW

12. An activity has optimistic time 4, most likely 6, and pessimistic 14 days. Using the PERT formula, what is its expected duration?

A. 6 days

B. 8 days

C. 7 days

D. 14 days

13. A rectangular channel 2 m wide carries 6 m³/s. Using yc = (q²/g)^(1/3) with q = Q/b, what is the critical depth?

A. 0.31 m

B. 1.50 m

C. 3.00 m

D. 0.97 m

14. A traverse course is 150 m long with an azimuth of 60°. What is its latitude?

A. 75 m

B. 130 m

C. 150 m

D. 60 m

15. A column carries a factored axial load of 1,200 kN with a moment of 80 kN·m. To assess adequacy under combined loading, the engineer uses:

A. A shear-friction equation

B. The Manning equation

C. A P-M interaction diagram

D. A flow net

16. The function $f(x) = x^3 - 3x$ has critical points at $x = \pm 1$. At which point does the local maximum occur?

A. $x = 0$

B. $x = 1$

C. $x = -1$

D. $x = 3$

17. A bond purchased for $950 has a face value of $1,000 and pays $50 annual interest. What is its current yield?

A. 5.00%

B. 5.26%

C. 10.0%

D. 4.75%

18. A project's earned value is $72,000 and its actual cost is $90,000. What is the cost variance?

A. −$8,000

B. −$18,000

C. +$10,000

D. +$18,000

19. A 3-hectare site (C = 0.7) receives a rainfall intensity of 40 mm/hr. Using Q = CiA/360, what is the peak runoff?

A. 0.233 m^3/s

B. 2.33 m^3/s

C. 0.023 m^3/s

D. 84 m^3/s

20. A footing on sand has a depth of 1.5 m and a soil unit weight of 18 kN/m^3. In the bearing capacity equation, what is the surcharge term q (= $\gamma \cdot Df$)?

A. 18 kPa

B. 27 kPa

C. 486 kPa

D. 1.5 kPa

21. A cable carrying a uniform horizontal load assumes the shape of a:

A. Straight line

B. Circular arc

C. Triangle

D. Parabola

22. A pipe flow has a Reynolds number of 50,000. The flow regime is:

A. Laminar

B. Turbulent

C. Critical exactly

D. Static

23. A solid shaft of diameter 60 mm carries a torque of 2 kN·m. Using $\tau = 16T/(\pi d^3)$, what is the maximum shear stress?

A. 23.6 MPa

B. 47.2 MPa

C. 94.4 MPa

D. 11.8 MPa

24. In a two-span continuous beam under uniform load, the maximum negative bending moment occurs:

A. At midspan

B. At the exterior supports

C. At the quarter points

D. Over the interior support

25. A plate slides over a 2 mm oil film ($\mu = 0.1$ Pa·s) at 0.5 m/s. Using $\tau = \mu(du/dy)$, what is the shear stress?

A. 25 Pa

B. 0.025 Pa

C. 250 Pa

D. 2.5 Pa

26. A clarifier removes 65% of an influent suspended-solids concentration of 300 mg/L. What is the effluent concentration?

A. 195 mg/L

B. 65 mg/L

C. 105 mg/L

D. 35 mg/L

27. A steel beam has an elastic section modulus of 5×10^{-4} m³ and a yield strength of 250 MPa. Using My = Fy·S, what is its yield moment?

A. 125 kN·m

B. 250 kN·m

C. 62.5 kN·m

D. 500 kN·m

28. An engineer sits on a board reviewing a project in which they hold a financial interest. The engineer should:

A. Vote on the project to influence the outcome

B. Conceal the interest and participate fully

C. Disclose the interest and recuse from the decision

D. Resign from the board permanently

29. A $1,000 deposit is made at the end of each year for 5 years at 6%, with (F/A, 6%, 5) = 5.6371. What is the accumulated future value?

A. $5,000

B. $5,637

C. $6,000

D. $4,212

30. A level circuit's allowable misclosure grows with the square root of the number of setups. This reflects:

A. A systematic error

B. The accumulation of random errors

C. A single blunder

D. Instrument miscalibration

31. An asset costs $25,000 with a $5,000 salvage value and a 5-year life. Using sum-of-years'-digits, what is the first-year depreciation?

A. $6,667

B. $4,000

C. $5,000

D. $1,333

32. What is the general solution of $d^2y/dx^2 + 9y = 0$?

A. y = Ce^(3x)

B. $y = C_1e^{(3x)} + C_2e^{(-3x)}$

C. $y = C_1x + C_2$

D. $y = C_1\cos(3x) + C_2\sin(3x)$

33. A storm hydrograph has a peak discharge of 25 m^3/s and a base flow of 5 m^3/s. What is the direct runoff peak?

A. 30 m^3/s

B. 25 m^3/s

C. 20 m^3/s

D. 5 m^3/s

34. Two beams of equal material carry the same central load; one has twice the depth (same width). Its deflection, compared with the shallower beam, is:

A. Doubled

B. Halved

C. One-eighth

D. Quadrupled

35. A 250 m radius curve is designed for 80 km/hr. Using $e + f = V^2/(127R)$, what is the required sum of superelevation and side friction?

A. 0.10

B. 0.20

C. 0.40

D. 0.05

36. A reservoir releases 12 m^3/s for 24 hours. What total volume is released?

A. 1.04×10^6 m^3

B. 288 m^3

C. 1.04×10^4 m^3

D. 12 m^3

37. Two materials are joined in series and carry the same axial force. The total elongation is the:

A. Sum of the individual elongations

B. Difference of the elongations

C. Average of the elongations

D. Product of the elongations

38. The ratio of a steel beam's plastic section modulus Z to its elastic section modulus S is the:

A. Slenderness ratio

B. Shape factor

C. Poisson's ratio

D. Modular ratio

39. A 3 m square footing carries 1,800 kN. Neglecting footing weight and surcharge, what is the net bearing pressure?

A. 600 kPa

B. 100 kPa

C. 200 kPa

D. 1,800 kPa

40. Concrete's tensile strength is approximately what fraction of its compressive strength?

A. About 10%

B. About 50%

C. About 90%

D. About 150%

41. An intersection has a critical flow-ratio sum of 0.70 and a total lost time of 16 s. Using Webster's optimum cycle $C_o = (1.5L + 5)/(1 - Y)$, what is the optimum cycle length?

A. 24 s

B. 48 s

C. 96.7 s

D. 145 s

42. A closed six-sided traverse's measured interior angles are compared to a theoretical sum of:

A. 720°

B. 360°

C. 1,080°

D. 540°

43. A trapezoidal distributed load varies from 4 kN/m to 10 kN/m over 5 m. What is the total load?

A. 50 kN

B. 35 kN

C. 70 kN

D. 14 kN

44. Compressing a schedule by overlapping design and construction phases is called:

A. Crashing

B. Fast-tracking

C. Leveling

D. Float allocation

45. A hydraulic jump dissipates energy as the flow changes from:

A. Turbulent to laminar

B. Subcritical to critical

C. Pressurized to open

D. Supercritical to subcritical

46. A soil has $k = 3\times10^{-5}$ m/s under a gradient of 0.04. What is the Darcy (discharge) velocity?

A. 7.5×10^{-4} m/s

B. 1.2×10^{-6} m/s

C. 1.2×10^{-4} m/s

D. 3×10^{-5} m/s

47. A road has a free-flow speed of 100 km/hr and a jam density of 120 veh/km. Using Greenshields' qmax = vf·kj/4, what is the maximum flow?

A. 3,000 veh/hr

B. 12,000 veh/hr

C. 1,500 veh/hr

D. 220 veh/hr

48. A trickling filter and an activated sludge process are both forms of:

A. Primary treatment

B. Disinfection

C. Secondary (biological) treatment

D. Tertiary filtration

49. A pavement designed for 2×10^{6} ESALs experiences traffic growth to 4×10^{6} cumulative ESALs. The pavement will likely:

A. Last twice as long

B. Be unaffected

C. Require less thickness

D. Reach its fatigue life sooner than designed

50. A cantilever beam carries a uniform load w over length L. What is the reaction shear at the fixed support?

A. $wL/2$

B. $wL^2/2$

C. wL

D. $wL^2/8$

51. A vehicle braking on a 4% downgrade, compared with a level road, has a stopping distance that is:

A. Longer, because gravity reduces deceleration

B. Shorter, because gravity helps stopping

C. Unchanged

D. Zero

52. The Laplace transform is a tool primarily used to solve:

A. Systems of linear algebraic equations

B. Probability distributions

C. Linear differential equations

D. Matrix determinants

53. A 200 N force acts at a 0.4 m moment arm and a 100 N force at a 0.2 m arm in the same sense. What is the total moment?

A. 100 N·m

B. 60 N·m

C. 300 N·m

D. 16 N·m

54. A992 structural steel is specified primarily by its minimum:

A. Density

B. Yield strength

C. Thermal conductivity

D. Color grade

55. A normally consolidated clay has a preconsolidation pressure equal to its current overburden. Its overconsolidation ratio is:

A. 0

B. 1

C. 2

D. Greater than 2

56. The secondary moment from an axial load acting on a beam-column's lateral deflection is the:

A. Poisson effect

B. Saint-Venant effect

C. Bauschinger effect

D. P-delta effect

57. A slump test gives 180 mm where 75–100 mm was specified. The mix is:

A. Too stiff for placement

B. Too wet (high slump) and likely over-watered

C. Exactly as specified

D. Of higher strength than designed

58. A retaining wall on clay is checked for a deep-seated rotational failure using:

A. A flow net

B. A slip-circle (slope stability) analysis

C. A Mohr's circle of stress

D. A unit hydrograph

59. In a unit-price construction contract, the final payment is determined by:

A. The lump sum bid only

B. The contractor's profit goal

C. A fixed amount regardless of quantities

D. Measured actual quantities times the unit prices

60. Adding silica fume to concrete primarily improves:

A. Workability of the fresh mix

B. The setting speed

C. The color uniformity

D. Strength and reduced permeability

61. A project has equivalent annual benefits of $50,000 and costs of $40,000. What is its benefit-cost ratio?

A. 0.80

B. 10,000

C. 1.25

D. 1.0

62. An EDM measures distance using the:

A. Magnetic field of the earth

B. Travel time or phase shift of a light or microwave signal

C. Barometric pressure difference

D. Optical stadia interval

63. A steel's ductility is commonly quantified by its:

A. Percent elongation at fracture

B. Compressive modulus

C. Density

D. Coefficient of thermal expansion

64. A 0.5 kg ball on a 1 m string swings as a pendulum. Using $T = 2\pi\sqrt{(L/g)}$, what is its period?

A. 0.32 s

B. 6.28 s

C. 2.01 s

D. 1.00 s

65. An interest rate of 18% per year compounded monthly has an effective annual rate of:

A. 18.00%

B. 1.50%

C. 19.56%

D. 21.00%

66. A professional engineer's continuing education requirement exists primarily to:

A. Maintain competence as technology and codes evolve

B. Increase licensing fees

C. Limit the number of engineers

D. Replace the original examination

67. What is the partial derivative of $f(x, y) = x^2y + 3y$ with respect to x?

A. $x^2 + 3$

B. $2y + 3$

C. x^2

D. $2xy$

68. A traffic signal's effective green equals the displayed green plus the:

A. Red interval

B. Pedestrian phase

C. All-red clearance only

D. Yellow change interval minus the lost time

69. A column's critical buckling stress $\sigma cr = \pi^2E/(KL/r)^2$ decreases as the:

A. Modulus increases

B. Slenderness ratio increases

C. Area increases

D. Yield strength increases

70. The method of joints solves truss member forces by applying at each joint:

A. The moment equation only

B. The deflection compatibility

C. The two force-equilibrium equations

D. The flexure formula

71. A 100 m pipe (f = 0.02, D = 0.2 m) carries water at 2 m/s. Using $h_f = fLV^2/(2gD)$, what is the friction head loss?

A. 0.20 m

B. 1.02 m

C. 2.04 m

D. 4.08 m

72. Choosing public safety over a schedule when asked to approve substandard work reflects the principle that:

A. Deadlines always take priority

B. Public welfare is the paramount obligation

C. The client's wishes govern

D. Cost is the deciding factor

73. A simply supported beam has a moment applied at one end. Its bending moment diagram varies:

A. Parabolically

B. As a constant

C. As a step function

D. Linearly from the applied moment to zero at the far support

74. What is the sum of an infinite geometric series with first term 8 and ratio 0.5?

A. 4

B. 8

C. 12

D. 16

75. A 2 kg mass moving at 3 m/s collides elastically head-on with a stationary 4 kg mass. What is the 2 kg mass's velocity after impact?

A. −1 m/s (rebounds)

B. +3 m/s

C. +1 m/s

D. 0 m/s

76. A divided highway with full access control and grade-separated interchanges is classified as a:

A. Local street

B. Collector road

C. Freeway

D. Arterial with at-grade intersections

77. A clean sand ($c' = 0$, $\varphi' = 35°$) is under an effective normal stress of 150 kPa. Using $\tau = \sigma' \tan\varphi'$, what is its shear strength?

A. 105 kPa

B. 150 kPa

C. 53 kPa

D. 35 kPa

78. A fatigue failure in a steel member results from:

A. A single static overload

B. Slow creep under sustained load

C. Corrosion alone

D. Repeated cyclic stress over many cycles

79. What is the value of the definite integral of x^2 from 0 to 3?

A. 3

B. 27

C. 9

D. 18

80. A reinforced concrete beam reaches its nominal moment capacity when the:

A. Tension steel yields and the concrete reaches its compressive limit

B. Concrete cracks in tension

C. Beam first deflects

D. Stirrups are installed

81. A ladder leans against a smooth wall at angle θ to the floor. As θ decreases (the ladder becomes more horizontal), the required floor friction to prevent slipping:

A. Decreases

B. Becomes zero

C. Remains constant

D. Increases

82. A water main's peak hourly demand relative to the average daily demand is expressed by a peaking factor that is generally:

A. Less than 1.0

B. Exactly 1.0

C. Greater than 1.0

D. Always 10.0

83. An 8 m simply supported beam has 10 kN at 2 m and 20 kN at 6 m from the left. What is the left reaction?

A. 30 kN

B. 12.5 kN

C. 17.5 kN

D. 15 kN

84. Liquefaction hazard is greatest in:

A. Dense gravel

B. Stiff overconsolidated clay

C. Bedrock

D. Loose saturated sand under cyclic loading

85. A thin-walled cylinder 1 m in diameter with a 10 mm wall carries an internal pressure of 2 MPa. Using $\sigma = pd/(2t)$, what is the hoop stress?

A. 25 MPa

B. 50 MPa

C. 200 MPa

D. 100 MPa

86. In a consolidation test, the compression index Cc is the slope of the e–log σ′ curve in the:

A. Recompression (reloading) region

B. Virgin compression (normally consolidated) region

C. Swelling region

D. Elastic rebound region

87. Retainage in a construction contract is:

A. The contractor's total profit

B. A penalty for late completion

C. The cost of permanent materials

D. A portion of payment withheld until satisfactory completion

88. The center of pressure on a submerged vertical plane surface lies:

A. Below the centroid of the area

B. Above the centroid

C. At the centroid

D. At the free surface

89. To solve all forces at a truss joint directly by the method of joints, the joint must have no more than how many unknowns?

A. 4

B. 3

C. 2

D. 1

90. A doubly reinforced concrete beam is used when:

A. The beam carries no load

B. Only shear is present

C. The section depth is limited and extra moment capacity is needed

D. The concrete is in tension only

91. A sag vertical curve at an underpass may be governed by:

A. Headlight sight distance

B. Passing sight distance

C. Stopping distance on a crest

D. Overhead clearance sight distance under the structure

92. A flow net has 5 flow channels and 10 equipotential drops. What is the shape factor (Nf/Nd)?

A. 50

B. 0.5

C. 2.0

D. 15

93. A construction project's mobilization cost covers:

A. The contractor's annual taxes

B. Moving equipment, setting up site offices, and initial setup

C. The final cleanup only

D. The owner's financing

94. A flywheel with a moment of inertia of 2 kg·m² rotates at 20 rad/s. What is its rotational kinetic energy?

A. 400 J

B. 40 J

C. 800 J

D. 20 J

95. An engineer endorses a product in advertising as superior without supporting evidence. This is:

A. Acceptable marketing

B. Required by the manufacturer

C. A standard professional service

D. A deceptive statement and ethics violation

96. On a topographic survey, closely spaced contour lines indicate:

A. Flat terrain

B. A water body

C. Steep terrain

D. A horizontal road

97. A project's earned value is below both its planned value and its actual cost. The project is:

A. Behind schedule and over budget

B. Ahead of schedule and under budget

C. On schedule and on budget

D. Complete

98. A beam fixed at both ends with a central point load has a maximum moment (PL/8) that, compared with a simply supported beam (PL/4), is:

A. Smaller

B. Larger

C. Equal

D. Zero

99. In a pipe flowing full, the vertical distance between the energy grade line and the hydraulic grade line equals the:

A. Elevation head

B. Pressure head

C. Friction slope

D. Velocity head

100. How many permutations of 4 distinct objects taken 2 at a time are there?

A. 6

B. 12

C. 24

D. 4

101. A 24-hour unit hydrograph is convolved with effective rainfall to produce the:

A. Rainfall intensity

B. Infiltration rate

C. Base flow only

D. Direct runoff hydrograph

102. A least-squares survey adjustment minimizes the:

A. Number of observations

B. Total traverse length

C. Largest single error only

D. Sum of the squares of the residuals

103. A simply supported beam carries a uniform load. Doubling the span (same load per unit length) increases the maximum moment by a factor of:

A. 4

B. 2

C. 8

D. 16

104. A particle in equilibrium under three concurrent forces can be represented as a closed:

A. Circle

B. Square

C. Single vector

D. Triangle (force triangle)

105. What is the probability of getting at least one head in two fair coin tosses?

A. 0.50

B. 0.75

C. 0.25

D. 1.0

106. A pile load test loads a pile to twice its design load to verify:

A. The soil's color

B. The pile's manufacturer

C. Its capacity and acceptable settlement

D. The groundwater chemistry

107. A water distribution system maintains a minimum residual pressure to:

A. Increase pipe friction

B. Reduce the demand

C. Ensure adequate flow and prevent contamination intrusion

D. Lower the pump cost only

108. A benchmark loop returns to its origin with a 0.03 m misclosure. This error is distributed to:

A. The first setup only

B. The largest reading only

C. A single random point

D. The intermediate points to force closure

109. A 1,000 kg car rounds an unbanked 100 m radius curve at 20 m/s. Using mv^2/r, what friction force is required?

A. 2,000 N

B. 4,000 N

C. 200 N

D. 8,000 N

110. The modular ratio in reinforced concrete design is the ratio of the:

A. Steel's modulus to the concrete's modulus

B. Concrete's strength to the steel's strength

C. Bar diameter to the cover

D. Span to the depth

PRACTICE EXAM 19 – ANSWER KEY AND EXPLANATIONS

1. B — $M = wL^2/8 + PL/4 = 8(6^2)/8 + 20(6)/4 = 36 + 30 = 66$ kN·m. The two midspan-maximum effects superimpose because both peak at the center. Their sum gives the total moment.

2. D — Shaft power = $\gamma QH/\eta = (9.81 \times 0.08 \times 40)/0.75 = 31.4/0.75 = 41.9$ kW. The water power is divided by efficiency to find the input. Losses make the shaft power exceed the useful output.

3. A — Total cost of A = 50,000 + 5(5,000) = 75,000; B = 30,000 + 5(9,000) = 75,000. With no interest, the higher first cost of A is exactly offset by its lower operating cost. The two are equal.

4. A — By continuity, $V_2 = A_1V_1/A_2 = (0.02 \times 2)/0.01 = 4$ m/s. Halving the area doubles the velocity. Mass is conserved through the throat.

5. D — $L = AS^2/658 = 6(200^2)/658 = 240{,}000/658 = 364.7$ m. The crest curve must be long enough to provide the required sight distance over the hump. A larger grade change demands a longer curve.

6. C — $t = Tv \cdot H^2/cv = 0.197(2.5^2)/2 = 0.197(6.25)/2 = 0.62$ yr. With double drainage, the path length H is half the layer thickness. The time scales with the square of that path.

7. B — Three reaction components (2 + 1) match the three equilibrium equations, so the frame is statically determinate. The equations exactly suffice. No redundancy exists.

8. C — Sealing a report with knowingly falsified data is a serious ethics violation regardless of who falsified it. The seal certifies the engineer's responsible review. Endorsing false data breaches the duty of honesty.

9. D — $Q = AV = \pi(0.075^2)(3) = 0.01767 \times 3 = 0.053$ m³/s. Discharge is the pipe area times velocity. The 0.15 m diameter gives a 0.075 m radius.

10. A — The eigenvalues of a diagonal matrix are its diagonal entries, here 2 and 3. The characteristic equation factors directly. No off-diagonal coupling exists.

11. A — Average power = ½mv²/t = ½(1,200)(24²)/12 = 345,600/12 = 28,800 W = 28.8 kW. The work done equals the kinetic energy gained. Dividing by time gives average power.

12. C — PERT expected time = (a + 4m + b)/6 = (4 + 24 + 14)/6 = 42/6 = 7 days. The weighted average emphasizes the most likely value. It estimates the mean activity duration.

13. D — yc = (q²/g)^(1/3) with q = 6/2 = 3, so (9/9.81)^(1/3) = 0.97 m. Critical depth depends on the unit discharge. It marks the minimum specific energy.

14. A — Latitude = L cos(azimuth) = 150 cos 60° = 150 × 0.5 = 75 m. The latitude is the north-south component. The cosine of 60° is one-half.

15. C — Combined axial load and bending are assessed with a P-M interaction diagram. It bounds the safe combinations of axial force and moment. Points inside the curve are acceptable.

16. C — $f'(x) = 3x^2 - 3 = 0$ gives $x = \pm 1$; $f''(x) = 6x$ is negative at $x = -1$, so the local maximum is there. A negative second derivative indicates a maximum. At x = +1 the curve is a minimum.

17. B — Current yield = annual interest/price = 50/950 = 0.0526 = 5.26%. It relates the coupon to the purchase price, not the face value. Buying below par raises the yield above the coupon rate.

18. B — Cost variance = EV − AC = 72,000 − 90,000 = −$18,000. A negative value shows the project is over budget. More was spent than the value earned.

19. A — Q = CiA/360 = 0.7 × 40 × 3/360 = 84/360 = 0.233 m³/s. The metric rational method uses the 1/360 factor for these units. Peak flow scales with C, intensity, and area.

20. B — Surcharge q = γ·Df = 18 × 1.5 = 27 kPa. It is the effective overburden at the footing base level. This term contributes to the bearing capacity through Nq.

21. D — A cable under a uniform horizontal load takes a parabolic shape. The distributed load produces a smoothly curving profile. A point-loaded cable instead forms straight segments.

22. B — A Reynolds number of 50,000 is well above 4,000, so the flow is turbulent. Inertial forces dominate viscous forces. Laminar flow requires Re below about 2,000.

23. B — $\tau = 16T/(\pi d^3) = 16(2{,}000)/[\pi(0.06^3)] = 32{,}000/6.79\times10^{-4} = 47.2$ MPa. Maximum torsional shear occurs at the shaft surface. The cube of the diameter governs.

24. D — In a continuous beam, the maximum negative moment occurs over the interior support. Continuity develops hogging there. It often governs the design.

25. A — $\tau = \mu(du/dy) = 0.1(0.5/0.002) = 0.1 \times 250 = 25$ Pa. The shear stress is viscosity times the velocity gradient. A thinner film gives a steeper gradient and higher stress.

26. C — Effluent = $300 \times (1 - 0.65) = 300 \times 0.35 = 105$ mg/L. A 65% removal leaves 35% of the influent solids. The remainder passes through.

27. A — $My = Fy \cdot S = 250 \times 10^6 \times 5 \times 10^{-4} = 125{,}000$ N·m = 125 kN·m. The yield moment uses the elastic section modulus. It marks the onset of yielding at the extreme fiber.

28. C — The engineer should disclose the financial interest and recuse from the decision. Voting on a project one profits from is a conflict of interest. Disclosure and recusal preserve integrity.

29. B — $F = A(F/A) = 1{,}000 \times 5.6371 = \$5{,}637$. The uniform-series compound-amount factor accumulates five deposits to year 5. Interest compounds on the growing balance.

30. B — Misclosure growing with the square root of the number of setups reflects the accumulation of random errors. Random errors combine in quadrature. Systematic errors instead accumulate linearly.

31. A — SYD first-year depreciation = $(5/15)(25{,}000 - 5{,}000) = 0.333 \times 20{,}000 = \$6{,}667$. The first year takes the largest fraction, 5 of the 15 digit-sum. The depreciable base is cost minus salvage.

32. D — The equation $d^2y/dx^2 + 9y = 0$ has roots $\pm 3i$, giving $y = C_1\cos(3x) + C_2\sin(3x)$. A positive constant produces oscillatory (sinusoidal) solutions. The frequency is the square root of 9.

33. C — Direct runoff peak = total peak − base flow = $25 - 5 = 20$ m³/s. Subtracting base flow isolates the storm response. Base flow is the sustained groundwater contribution.

34. C — Doubling the depth increases I by $2^3 = 8$, and since deflection $\propto 1/I$, the deflection becomes one-eighth. Depth is far more effective than width. The cube relationship dominates.

35. B — $e + f = V^2/(127R) = 80^2/(127 \times 250) = 6{,}400/31{,}750 = 0.20$. This balances the centrifugal demand against superelevation and side friction. The radius and speed set the value.

36. A — Volume = flow × time = $12 \times 86{,}400 = 1{,}036{,}800 \approx 1.04 \times 10^6$ m³. Multiplying by the seconds in a day gives the daily volume. Unit consistency is essential.

37. A — For materials in series carrying the same force, the total elongation is the sum of the individual elongations. Each segment stretches independently. The deformations add.

38. B — The ratio Z/S is the shape factor. It measures the reserve between first yield and full plastic capacity. It depends on the cross-sectional shape.

39. C — Bearing pressure = load/area = $1{,}800/(3 \times 3) = 1{,}800/9 = 200$ kPa. A square footing spreads the load over its base. Uniform pressure is assumed for a concentric load.

40. A — Concrete's tensile strength is roughly 10% of its compressive strength. This weakness in tension is why steel reinforcement is added. The ratio guides cracking analysis.

41. C — $Co = (1.5L + 5)/(1 - Y) = (1.5 \times 16 + 5)/(1 - 0.70) = 29/0.30 = 96.7$ s. Webster's formula gives the cycle that minimizes delay. Higher lost time or flow ratio lengthens it.

42. A — Interior angles of a six-sided traverse sum to $(6 - 2) \times 180° = 720°$. The polygon angle-sum formula gives the theoretical total. Misclosure is the deviation from it.

43. B — Total trapezoidal load = $\frac{1}{2}(4 + 10)(5) = \frac{1}{2}(14)(5) = 35$ kN. The total equals the area of the load diagram. The average intensity times the length gives the same result.

44. B — Overlapping design and construction phases is fast-tracking. It shortens the schedule by parallelizing work. Crashing instead adds resources to critical activities.

45. D — A hydraulic jump converts supercritical flow to subcritical flow, dissipating energy. The abrupt depth increase loses kinetic energy to turbulence. It is used in stilling basins.

46. B — Darcy velocity = $ki = 3\times10^{-5} \times 0.04 = 1.2\times10^{-6}$ m/s. It is the apparent velocity over the gross area. The true seepage velocity is higher.

47. A — $qmax = vf \cdot kj/4 = 100 \times 120/4 = 3{,}000$ veh/hr. The Greenshields model peaks flow at half the jam density. The product over four gives the capacity.

48. C — Both trickling filters and activated sludge are secondary (biological) treatment processes. They use microorganisms to degrade dissolved organics. Primary treatment removes settleable solids first.

49. D — Doubling the cumulative ESALs to twice the design value means the pavement reaches its fatigue life sooner than designed. Pavement damage accumulates with load repetitions. Excess traffic shortens its service life.

50. C — The fixed-support reaction shear of a uniformly loaded cantilever is the total load, wL. The support must carry the entire distributed load. Shear is greatest there.

51. A — On a downgrade, gravity reduces the effective deceleration, so the stopping distance is longer than on level ground. The slope adds a forward component. Braking must overcome both inertia and gravity.

52. C — The Laplace transform is used primarily to solve linear differential equations. It converts them into algebraic equations in the transform domain. The solution is then inverted back.

53. A — Total moment = $200(0.4) + 100(0.2) = 80 + 20 = 100$ N·m. Moments in the same sense add. Each force contributes its force times its arm.

54. B — A992 structural steel is specified by its minimum yield strength (50 ksi). The grade designation reflects strength requirements. It is the standard for wide-flange shapes.

55. B — A normally consolidated clay has its preconsolidation pressure equal to the current overburden, giving OCR = 1. It has never experienced a higher past stress. Overconsolidated clays have OCR greater than 1.

56. D — The secondary moment from axial load acting on lateral deflection is the P-delta effect. The deflection increases the moment, which increases the deflection further. It must be considered in slender members.

57. B — A 180 mm slump where 75–100 mm was specified means the mix is too wet and likely over-watered. Excess water raises the slump and lowers strength. The mix is out of specification.

58. B — A deep-seated rotational failure of a wall on clay is analyzed with a slip-circle (slope stability) analysis. It checks failure along a curved surface through the soil. This is a global stability check.

59. D — In a unit-price contract, final payment equals the measured actual quantities times the unit prices. Quantities are verified in the field. This allocates quantity risk to the owner.

60. D — Silica fume improves concrete's strength and reduces its permeability. The fine particles fill voids and react with calcium hydroxide. The result is a denser, more durable matrix.

61. C — B/C ratio = benefits/costs = 50,000/40,000 = 1.25. A ratio above 1.0 means benefits exceed costs. The project is economically justified.

62. B — An EDM measures distance from the travel time or phase shift of a light or microwave signal. It times the signal's round trip to the prism. This gives high-precision distances.

63. A — Ductility is commonly quantified by the percent elongation at fracture. It measures the plastic strain a material sustains before breaking. Higher elongation indicates greater ductility.

64. C — $T = 2\pi\sqrt{(L/g)} = 2\pi\sqrt{(1/9.81)} = 2\pi(0.319) = 2.01$ s. The pendulum period depends on length and gravity, not mass. A 1 m pendulum swings in about two seconds.

65. C — Effective rate $= (1 + 0.18/12)^{12} - 1 = (1.015)^{12} - 1 = 0.1956 = 19.56\%$. Monthly compounding raises the effective rate above the 18% nominal. Interest earns interest each month.

66. A — Continuing education maintains competence as technology and codes evolve. Engineering practice changes over a career. Ongoing learning protects the public.

67. D — $\partial/\partial x(x^2y + 3y) = 2xy$, treating y as constant. The first term differentiates to 2xy and the 3y term vanishes. Only x-dependence is differentiated.

68. D — Effective green equals the displayed green plus the yellow change interval minus the lost time. It is the time effectively available for vehicle movement. Drivers use part of the yellow.

69. B — Critical buckling stress $\sigma cr = \pi^2E/(KL/r)^2$ decreases as the slenderness ratio increases. More slender columns buckle at lower stress. Slenderness inversely controls capacity.

70. C — The method of joints applies the two force-equilibrium equations ($\Sigma F_x = 0$, $\Sigma F_y = 0$) at each pin joint. Concurrent forces at a joint produce no moment equation. Two unknowns can be solved per joint.

71. C — $h_f = fLV^2/(2gD) = 0.02(100)(2^2)/(2 \times 9.81 \times 0.2) = 0.02 \times 100/0.2 \times 0.204 = 2.04$ m. Friction loss grows with the square of velocity and pipe length. A larger diameter reduces it.

72. B — Choosing safety over schedule reflects that public welfare is the paramount obligation. This duty overrides deadlines, cost, and client wishes. It is the foremost ethical principle.

73. D — An end moment on a simple beam produces a moment diagram varying linearly from the applied moment to zero at the far support. With no transverse load, shear is constant and moment is linear. The diagram is a straight line.

74. D — $S = a/(1 - r) = 8/(1 - 0.5) = 8/0.5 = 16$. The infinite geometric series converges because $|r| < 1$. The sum is the first term over one minus the ratio.

75. A — $v_1' = [(m_1 - m_2)/(m_1 + m_2)]v = (2 - 4)/6 = -1$ m/s. The lighter mass rebounds off the heavier one. The negative sign indicates reversed direction.

76. C — A divided highway with full access control and grade-separated interchanges is a freeway. These features define the highest functional class. Arterials and collectors have at-grade access.

77. A — $\tau = \sigma' \tan\varphi' = 150 \times \tan 35° = 150 \times 0.700 = 105$ kPa. For clean sand the cohesion is zero. Strength is purely frictional.

78. D — Fatigue failure results from repeated cyclic stress over many cycles. Cracks initiate and grow under each cycle until fracture. It occurs at stresses below the static strength.

79. C — $\int_0^3 x^2\,dx = [x^3/3]_0^3 = 27/3 = 9$. The power rule integrates x^2 to $x^3/3$. Evaluating over the limits gives nine.

80. A — A reinforced concrete beam reaches its nominal moment capacity when the tension steel yields and the concrete reaches its compressive strain limit. This defines flexural failure. Under-reinforced beams yield the steel first.

81. D — As the ladder becomes more horizontal (θ decreasing), the required floor friction to prevent slipping increases. A flatter ladder produces a larger horizontal wall reaction to resist. Friction must rise to balance it.

82. C — A peak hourly demand exceeds the average daily demand, so the peaking factor is greater than 1.0. Water mains are sized for these peaks. The factor captures demand variability.

83. B — Taking moments about the right support: $R_L(8) = 10(6) + 20(2) = 60 + 40 = 100$, so $R_L = 12.5$ kN. The reaction balances the load moments about the far support. Each load contributes by its distance.

84. D — Liquefaction hazard is greatest in loose saturated sand under cyclic loading. Shaking raises pore pressure until effective stress vanishes. Dense soils and clays resist this.

85. D — Hoop stress = $pd/(2t) = 2\times10^6 \times 1/(2 \times 0.01) = 2\times10^6/0.02 = 100$ MPa. The circumferential stress is the governing thin-wall stress. It is twice the longitudinal stress.

86. B — Cc is the slope of the e–log σ′ curve in the virgin (normally consolidated) compression region. This is the steep portion beyond the preconsolidation pressure. It governs settlement of normally consolidated clay.

87. D — Retainage is a portion of payment withheld until satisfactory completion. It protects the owner against incomplete or defective work. It is released at closeout.

88. A — The center of pressure on a submerged vertical surface lies below the centroid. Pressure increases with depth, shifting the resultant downward. The offset depends on the surface geometry.

89. C — Each joint provides two equilibrium equations, so it must have no more than two unknowns to be solved directly. With three or more, an additional joint or the method of sections is needed. Two unknowns match the two equations.

90. C — A doubly reinforced beam is used when the section depth is limited and extra moment capacity is needed. Compression steel supplements the limited concrete. It also reduces long-term deflection.

91. D — A sag curve at an underpass may be governed by overhead clearance sight distance under the structure. The structure can block the driver's view of the road ahead. This can control the curve length.

92. B — Shape factor = Nf/Nd = 5/10 = 0.5. It is the ratio of flow channels to equipotential drops. This factor scales the seepage quantity.

93. B — Mobilization cost covers moving equipment, setting up site offices, and initial setup. It is incurred before productive work begins. It is often a separate pay item.

94. A — Rotational KE = $\frac{1}{2}I\omega^2 = \frac{1}{2}(2)(20^2) = \frac{1}{2}(2)(400) = 400$ J. It depends on the moment of inertia and the square of angular speed. The flywheel stores this energy.

95. D — Endorsing a product as superior without supporting evidence is a deceptive statement and an ethics violation. Engineers must make truthful, substantiated public statements. Unsupported endorsements mislead.

96. C — Closely spaced contour lines indicate steep terrain. The contours crowd where elevation changes rapidly over a short distance. Widely spaced contours show flat ground.

97. A — Earned value below both planned value and actual cost means the project is behind schedule and over budget. EV < PV indicates schedule slip; EV < AC indicates cost overrun. Both performance measures are unfavorable.

98. A — A fixed-fixed beam's maximum moment (PL/8) is smaller than a simple beam's (PL/4). The end fixity develops support moments that relieve the midspan. Fixity makes the beam more efficient.

99. D — The vertical gap between the energy and hydraulic grade lines equals the velocity head. The velocity head represents the kinetic energy of the flow. Adding it to the HGL gives the total energy line.

100. B — $P(4,2) = 4!/(4 - 2)! = 24/2 = 12$. Permutations count ordered arrangements. There are twelve ordered pairs from four objects.

101. D — A unit hydrograph convolved with effective rainfall produces the direct runoff hydrograph. The unit response is scaled and superimposed for the storm. Base flow is added separately.

102. D — Least-squares adjustment minimizes the sum of the squares of the residuals. It produces the statistically most probable values. It distributes errors optimally across observations.

103. A — Maximum moment $wL^2/8$ grows with the square of span, so doubling L multiplies it by four. The moment is highly sensitive to span length. This is why long spans need much deeper beams.

104. D — Three concurrent forces in equilibrium form a closed force triangle. The vectors placed head to tail return to the start. Closure means the resultant is zero.

105. B — $P(\text{at least one head}) = 1 - P(\text{no heads}) = 1 - 0.25 = 0.75$. The complement is the probability of two tails. Subtracting from one gives three-quarters.

106. C — A pile load test loads the pile beyond design load to verify its capacity and acceptable settlement. It confirms the pile performs as designed. Results validate the foundation.

107. C — A minimum residual pressure ensures adequate flow and prevents contamination intrusion. Positive pressure keeps outside water from entering through leaks. It protects water quality and service.

108. D — A level loop's misclosure is distributed among the intermediate points to force closure. The known endpoint must reproduce the starting elevation. The correction spreads the error.

109. B — Friction force $= mv^2/r = 1{,}000(20^2)/100 = 400{,}000/100 = 4{,}000$ N. It supplies the centripetal force on the unbanked curve. The force grows with the square of speed.

110. A — The modular ratio is the ratio of the steel's modulus to the concrete's modulus (E_s/E_c). It converts steel area to an equivalent concrete area in transformed-section analysis. It reflects the relative stiffness.