PRACTICE EXAM 10 : FE CIVIL SIMULATION (110 QUESTIONS)

110 questions. Recommended time: 5 hours 20 minutes.

1. A soil sample has a moist unit weight of 19.6 kN/m³ at a water content of 12%. What is its dry unit weight?

A. 16.0 kN/m³

B. 17.5 kN/m³

C. 19.6 kN/m³

D. 21.9 kN/m³

2. Two forces act at the same point: 40 N directed due east and 30 N directed due north. What is the magnitude of their resultant?

A. 50 N

B. 70 N

C. 10 N

D. 35 N

3. Water (kinematic viscosity 1.0×10^{-6} m²/s) flows in a 0.05 m diameter pipe at 1 m/s. What is the Reynolds number?

A. 5,000

B. 500

C. 50,000

D. 500,000

4. A horizontal curve has a degree of curve of 5° (arc definition). What is its radius ($R = 5{,}729.58/D$)?

A. 286 ft

B. 573 ft

C. 1,000 ft

D. 1,146 ft

5. What is the future value of $5,000 invested for 3 years at 8% compounded annually?

A. $6,200

B. $6,299

C. $5,400

D. $7,000

6. A rectangular beam section is 150 mm wide and 300 mm deep. What is its elastic section modulus ($S = bh^2/6$)?

A. 1.13×10^6 mm³

B. 2.25×10^6 mm³

C. 3.38×10^6 mm³

D. 6.75×10^6 mm³

7. The design method that applies load factors greater than 1.0 to loads and resistance factors less than 1.0 to capacity is:

A. Load and Resistance Factor Design

B. Allowable Stress Design

C. Working Stress Design

D. Service Load Design

8. Solve for x: $3^x = 81$.

A. 2

B. 3

C. 4

D. 27

9. A rectangular channel 2 m wide carries 4 m^3/s at a flow depth of 1 m. What is the average velocity?

A. 0.5 m/s

B. 1 m/s

C. 2 m/s

D. 4 m/s

10. A car rounds a 50 m radius curve at 15 m/s. What is the centripetal acceleration?

A. 0.3 m/s^2

B. 3.0 m/s^2

C. 7.5 m/s^2

D. 4.5 m/s^2

11. Granular activated carbon in water treatment is most effective at removing:

A. Dissolved organic compounds and odors

B. Dissolved calcium hardness

C. Suspended grit particles

D. Dissolved oxygen gas

12. A backsight reading of 2.45 m is taken on a benchmark at elevation 100.00 m. What is the height of instrument (HI)?

A. 97.55 m

B. 100.00 m

C. 2.45 m

D. 102.45 m

13. A direct shear test on a clean sand gives a failure shear stress of 60 kPa at a normal stress of 100 kPa. What is the friction angle?

A. 45°

B. 31°

C. 60°

D. 21°

14. An asset costs $80,000 with a 6-year life. What is the first-year depreciation using the double-declining-balance method?

A. $12,000

B. $13,333

C. $26,667

D. $80,000

15. A 600 N weight hangs from two vertical cables that share the load equally. What is the tension in each cable?

A. 600 N

B. 300 N

C. 150 N

D. 1,200 N

16. What pressure head of water corresponds to a pressure of 200 kPa ($\gamma = 9.81$ kN/m³)?

A. 20.4 m

B. 2.04 m

C. 40.8 m

D. 200 m

17. For a given set of vehicle speeds, the time-mean speed is always:

A. Less than the space-mean speed

B. Equal to zero at capacity

C. Independent of speed variance

D. Greater than or equal to the space-mean speed

18. For a simply supported beam carrying a uniformly distributed load, the maximum shear force occurs at the:

A. Midspan

B. Supports

C. Quarter points

D. No location along the span

19. A right triangle has legs of length 5 and 12. What is the length of the hypotenuse?

A. 13

B. 17

C. 7

D. 60

20. A soil has D_{60} = 0.6 mm and D_{10} = 0.1 mm. What is its coefficient of uniformity (Cu)?

A. 0.17

B. 0.5

C. 0.06

D. 6

21. The arithmetic gradient present-worth factor (P/G) is used for cash flows that:

A. Increase by a constant amount each period

B. Increase by a constant percentage each period

C. Remain uniform each period

D. Occur only once in the future

22. A 2 kg block slides down a frictionless incline of 30°. What is its acceleration?

A. 4.9 m/s^2

B. 9.81 m/s^2

C. 8.5 m/s^2

D. 2.45 m/s^2

23. Bernoulli's equation is fundamentally a statement of the conservation of:

A. Mass flow rate

B. Linear momentum

C. Angular velocity

D. Mechanical energy

24. The interior angles of a closed six-sided traverse should sum to:

A. 360°

B. 540°

C. 720°

D. 900°

25. A short column loaded with an eccentric axial force experiences combined:

A. Torsion and shear only

B. Pure tension only

C. Bending only

D. Axial compression and bending

26. What is the population variance of the data set {2, 4, 6}?

A. 2.00

B. 2.67

C. 4.00

D. 8.00

27. A pile driven to refusal in dense sand carries its load primarily through:

A. Negative skin friction

B. Lateral earth pressure

C. End bearing at the tip

D. Buoyant uplift

28. The internal rate of return of a project is the interest rate at which:

A. Benefits are maximized

B. The net present worth equals zero

C. The payback period is shortest

D. Depreciation equals salvage value

29. Friction head loss in a pipe increases with:

A. Increasing velocity and pipe length

B. Increasing pipe diameter only

C. Decreasing wall roughness only

D. Decreasing flow rate

30. Under ideal conditions, the maximum capacity of a basic freeway lane is approximately:

A. 1,000 pc/h/ln

B. 1,500 pc/h/ln

C. 1,800 pc/h/ln

D. 2,400 pc/h/ln

31. A 3 m steel rod (E = 200 GPa, A = 300 mm^2) carries 30 kN of tension. What is its elongation?

A. 0.5 mm

B. 1.0 mm

C. 1.5 mm

D. 3.0 mm

32. A flexible cable carrying only its own self-weight hangs in the shape of a:

A. Parabola

B. Straight line

C. Circular arc

D. Catenary

33. The primary purpose of a grit chamber in wastewater treatment is to remove:

A. Dissolved nutrients

B. Heavy inorganic grit and sand

C. Floating grease and scum

D. Biological floc

34. Equal monthly payments on a $12,000 loan at 1% per month over 24 months are computed using the factor:

A. (F/P, 1%, 24)

B. (P/A, 1%, 24)

C. (A/P, 1%, 24)

D. (F/A, 1%, 24)

35. For the line $y = 2x - 1$, what is the value of y when $x = 3$?

A. 2

B. 3

C. 4

D. 5

36. In soil mechanics, effective stress directly controls a soil's:

A. Shear strength and volume change

B. Specific gravity of solids

C. Color and surface texture

D. Total unit weight only

37. The kinematic viscosity of a fluid equals its dynamic viscosity divided by its:

A. Velocity

B. Pressure

C. Density

D. Temperature

38. A two-phase traffic signal has a lost time of 4 s per phase. What is the total lost time per cycle?

A. 2 s

B. 4 s

C. 8 s

D. 16 s

39. Concrete cover over reinforcing steel is provided mainly to:

A. Increase the beam's clear span

B. Protect the steel from corrosion and fire

C. Reduce the concrete self-weight

D. Eliminate shear reinforcement

40. A project with a payback period of 4 years means that:

A. The project lasts only 4 years total

B. The annual rate of return is 4%

C. The initial cost is recovered in 4 years

D. Depreciation ends after 4 years

41. The resultant of two equal, opposite, parallel forces not acting along the same line is:

A. A single larger resultant force

B. Zero in every respect

C. A couple (pure moment)

D. A net tensile force

42. What is the derivative of ln(x)?

A. 1/x

B. x

C. ln(x)/x

D. e^x

43. A 100 mm pipe reduces to a 50 mm pipe. By continuity, the velocity in the smaller pipe is:

A. Twice as large

B. Half as large

C. Four times as large

D. The same

44. The compression index Cc obtained from a consolidation test is the slope of the:

A. Stress-strain curve at failure

B. Grain-size distribution curve

C. Seepage flow-net diagram

D. Void ratio versus log effective stress curve

45. An acceleration lane at a freeway entrance ramp is provided so that merging vehicles can:

A. Reach mainline speed before merging

B. Stop and wait for a gap

C. Bypass the toll plaza

D. Reduce the design speed

46. In a defender-challenger replacement analysis, the relevant value of the existing asset is its:

A. Original purchase price

B. Current market value

C. Accumulated depreciation

D. Book value only

47. A net force of 20 N acts on a 5 kg mass. What is its acceleration?

A. 100 m/s^2

B. 4 m/s^2

C. 0.25 m/s^2

D. 25 m/s²

48. The transverse shear stress in a rectangular beam is maximum at the:

A. Top fiber

B. Bottom fiber

C. Neutral axis

D. Outer surface only

49. A stadia distance measurement multiplies the rod-interval reading by:

A. The instrument height

B. The stadia interval factor (≈100)

C. The magnetic declination

D. The earth's curvature

50. A hydraulic jump in an open channel dissipates energy and converts the flow from:

A. Laminar to turbulent

B. Subcritical to supercritical

C. Pressurized to free-surface

D. Supercritical to subcritical

51. For a simply supported beam carrying a single concentrated load at midspan, the bending moment diagram has what shape?

A. Rectangular and uniform

B. Parabolic over the full span

C. Triangular, peaking at midspan

D. Zero everywhere along the span

52. Two alternatives have identical first cost and life. The one with lower annual operating cost has the:

A. Higher present worth of costs

B. Longer payback period

C. Lower rate of return

D. Lower equivalent uniform annual cost

53. Convert 45° to radians.

A. $\pi/4$

B. $\pi/2$

C. $\pi/3$

D. $\pi/6$

54. An overconsolidation ratio (OCR) greater than 1 indicates that the soil:

A. Is normally consolidated

B. Is currently fully saturated

C. Was loaded more heavily in the past

D. Has zero shear strength

55. Discharge over a rectangular sharp-crested weir is proportional to the head raised to the power:

A. 1/2

B. 1.0

C. 2.0

D. 3/2

56. Highway crash rate is most commonly normalized per:

A. Lane width in feet

B. Signal cycle length

C. Number of through lanes

D. Million vehicle-miles traveled

57. A planar truss with j joints is internally determinate when the number of members m equals:

A. $j - 2$

B. $2j - 3$

C. $3j - 2$

D. $j + 3$

58. Inflation is properly accounted for in a cash-flow analysis by:

A. Ignoring it entirely

B. Adding it to depreciation

C. Using only nominal salvage value

D. Using consistent dollar and interest-rate bases

59. A wheel of radius 0.4 m rolls without slipping at a center speed of 8 m/s. What is its angular velocity?

A. 3.2 rad/s

B. 8 rad/s

C. 0.05 rad/s

D. 20 rad/s

60. A slender column fails by elastic instability when the axial load reaches the:

A. Yield load in tension

B. Shear rupture load

C. Euler critical buckling load

D. Fatigue endurance limit

61. In Manning's equation, the velocity is proportional to the hydraulic radius raised to the power:

A. 1/2

B. 1.0

C. 2/3

D. 3/2

62. In soil gradation, the boundary between coarse-grained and fine-grained soil is the:

A. No. 200 sieve (0.075 mm)

B. No. 4 sieve (4.75 mm)

C. No. 40 sieve

D. One-inch sieve

63. A level loop closing with a measured error over a known distance is checked against:

A. The instrument's serial number

B. An allowable error proportional to the route length

C. The magnetic declination correction

D. The number of turning points only

64. A perpetual scholarship is to pay $4,000 per year at an interest rate of 5%. What endowment is required?

A. $80,000

B. $4,200

C. $200,000

D. $20,000

65. What is the area of the region bounded by the line $y = x$, the x-axis, and the vertical line $x = 4$?

A. 4

B. 16

C. 2

D. 8

66. A 10 kN force acts at 36.87° above the horizontal (a 3-4-5 triangle orientation). What is its vertical component?

A. 10 kN

B. 8 kN

C. 6 kN

D. 4 kN

67. The ductility of a structural steel member allows it to:

A. Resist all forms of corrosion

B. Carry only compressive loads

C. Deform plastically before fracture

D. Eliminate the need for connections

68. Specific energy in open-channel flow is defined as the sum of:

A. Pressure head and elevation head

B. Friction loss and minor losses

C. Total head plus datum elevation

D. Flow depth plus velocity head

69. A footing on saturated clay loaded rapidly is most appropriately analyzed using:

A. Undrained, total-stress ($\varphi = 0$) analysis

B. Fully drained effective-stress analysis

C. Seepage flow-net analysis

D. Compaction curve analysis

70. The yellow change interval plus the all-red interval together constitute the:

A. Clearance (change plus all-red) interval

B. Effective green time

C. Saturation flow period

D. Pedestrian walk interval

71. Because depreciation reduces taxable income, it produces a benefit referred to as the:

A. Salvage premium

B. Depreciation tax shield

C. Capital gain allowance

D. Sunk cost recovery

72. Two independent events each have a probability of 0.5. What is the probability that at least one occurs?

A. 0.25

B. 0.50

C. 0.75

D. 1.00

73. Principal stresses act on the specific planes where the:

A. Normal stress is zero

B. Strain is at a maximum

C. Shear stress is zero

D. Cross-section is thinnest

74. The hydraulic depth of an open channel equals the flow area divided by the:

A. Top water-surface width

B. Wetted perimeter

C. Channel bottom width

D. Hydraulic radius

75. An idealized pin connection in a steel frame transfers:

A. Moment but not force

B. Force but not moment

C. Both force and moment

D. Neither force nor moment

76. A retaining wall has a level cohesionless backfill with $\varphi = 30°$. What is the active earth pressure coefficient $K_a = \tan^2(45 - \varphi/2)$?

A. 0.33

B. 0.50

C. 3.0

D. 1.0

77. GPS positioning fundamentally relies on measuring:

A. Signal travel times from multiple satellites

B. The local magnetic field strength

C. Atmospheric barometric pressure

D. Star angles observed at night

78. A 1,000 kg car slows from 20 m/s to 10 m/s. What is the magnitude of the change in kinetic energy?

A. 100 kJ

B. 50 kJ

C. 150 kJ

D. 300 kJ

79. Finding the future worth of a present lump sum plus a uniform annual series requires combining the:

A. (P/A) factor only

B. (F/P) and (F/A) factors

C. (A/G) factor only

D. (P/F) and (P/G) factors

80. The general solution of the differential equation dy/dx = ky is:

A. $y = Ce^{kx}$

B. $y = kx + C$

C. $y = C/x$

D. $y = \sin(kx)$

81. A simply supported beam of span L carries two equal point loads P located at the third points (L/3 and 2L/3 from one support). What is the maximum bending moment?

A. PL/8

B. PL/4

C. PL/2

D. PL/3

82. The operating point of a centrifugal pump is located at the intersection of the pump curve and the:

A. Efficiency axis

B. System (head-loss) curve

C. Suction line alone

D. Atmospheric pressure line

83. Settlement of a footing founded on clean sand typically occurs:

A. Almost immediately upon loading

B. Over many years by consolidation

C. Only after the water table rises

D. Only under repeated cyclic loading

84. Superelevation on a highway curve is provided primarily to counteract:

A. Headwind air resistance

B. Centrifugal force on the curve

C. Pavement thermal expansion

D. Vehicle braking force

85. In an economic comparison of alternatives, the "do nothing" option serves as:

A. The most expensive available option

B. A required mandatory selection

C. A penalty imposed for inaction

D. A baseline for incremental comparison

86. What is the slope of the tangent line to $y = x^2$ at $x = 3$?

A. 3

B. 6

C. 9

D. 2

87. A bolt subjected to simultaneous tension and shear is evaluated using:

A. Tension capacity alone

B. Shear capacity alone

C. Bending capacity alone

D. A combined tension-shear interaction

88. The total dynamic head a pump must supply includes the static lift, friction losses, and the:

A. Static lift component only

B. Friction losses only

C. Static lift, friction, and velocity head

D. Pump mechanical efficiency

89. The disinfection byproduct of greatest concern when chlorine reacts with natural organic matter is:

A. Dissolved oxygen

B. Calcium carbonate

C. Trihalomethanes

D. Ammonia gas

90. The slenderness ratio of a column is defined as the:

A. Length multiplied by the area

B. Area divided by the length

C. Moment divided by the length

D. Effective length divided by the radius of gyration

91. In an earth dam, the phreatic surface is the:

A. Bottom of the dam foundation

B. Top seepage flow line at atmospheric pressure

C. Crest of the embankment

D. Downstream toe drain location

92. Neglecting air resistance, a projectile's horizontal velocity during flight:

A. Remains constant throughout

B. Increases due to gravity

C. Decreases to zero at the apex

D. Reverses direction at the peak

93. A geometric gradient cash-flow series increases each period by:

A. A constant dollar amount

B. A random fluctuating amount

C. A decreasing amount only

D. A constant percentage

94. A data set has the five-number summary minimum = 10, first quartile = 30, median = 50, third quartile = 70, and maximum = 90. What is the median value?

A. 30

B. 50

C. 70

D. 40

95. The center of gravity of a uniform straight rod is located at its:

A. One end

B. Geometric midpoint

C. One-third point

D. Quarter point

96. Open-channel flow is classified as subcritical when the Froude number is:

A. Equal to 1

B. Greater than 1

C. Less than 1

D. Equal to zero

97. A fillet weld is typically designed to resist applied load through its:

A. Effective throat area in shear

B. Full base metal in tension

C. Bolt bearing surface only

D. Weld length in bending only

98. The shrinkage limit of a soil is the water content at which:

A. The soil first becomes a liquid

B. Further drying causes no additional volume reduction

C. The plasticity index reaches its maximum

D. The soil becomes fully saturated

99. In highway design, the k-factor represents the proportion of:

A. Trucks in the traffic stream

B. Green time to cycle length

C. Crashes per million miles

D. AADT occurring in the design hour

100. When comparing alternatives with unequal service lives by present worth, the proper approach is to use:

A. A common study period, such as the least common multiple of the lives

B. Only the shorter of the two lives

C. Only the longer of the two lives

D. The simple average of the two lives

101. What is the indefinite integral of 1/x dx?

A. $x^2/2 + C$

B. $-1/x^2 + C$

C. $e^x + C$

D. $\ln|x| + C$

102. Conservation of linear momentum applies to a collision when:

A. External forces are negligible

B. Kinetic energy alone is conserved

C. The objects always stick together

D. Friction is at its maximum

103. In a thin-walled cylindrical pressure vessel, the hoop (circumferential) stress is:

A. Twice the longitudinal stress

B. Half the longitudinal stress

C. Equal to the longitudinal stress

D. Zero

104. In the Darcy-Weisbach equation, friction head loss is proportional to velocity raised to the power:

A. 0.5

B. 1

C. 1.5

D. 2

105. The ultimate bearing capacity of a shallow footing increases with:

A. Decreasing footing width

B. Increasing footing width and soil friction angle

C. A rising groundwater table alone

D. Higher soil water content

106. A moment-resisting frame resists lateral loads primarily through:

A. Tension in diagonal bracing

B. In-plane stiffness of shear walls

C. Friction within the floor diaphragm

D. Bending at rigid beam-column joints

107. A topographic survey produces a map that depicts:

A. Horizontal positions together with elevation contours

B. Only the property boundary lines

C. Only the soil classification zones

D. Only the underground utility locations

108. The benefit-cost ratio method of evaluation is most commonly applied to:

A. Public-sector (government) projects

B. Personal credit card balances

C. Stock option pricing models

D. Private bond trading desks

109. A binomial distribution has n = 10 and p = 0.3. What is its mean?

A. 0.3

B. 3.0

C. 7.0

D. 10

110. An engineer who discovers that a completed structure poses an imminent danger to public safety must:

A. Wait until the entire project is formally closed out

B. Notify only the contractor in private

C. Promptly notify the appropriate authority

D. Take no action without a court order

PRACTICE EXAM 10 — Answer Key and Explanations

1. B — $\gamma_d = \gamma/(1 + w) = 19.6/1.12 = 17.5$ kN/m³. The dry unit weight removes the water's contribution from the moist unit weight. This value is the target for field compaction control.
2. A — $R = \sqrt{(40^2 + 30^2)} = \sqrt{2{,}500} = 50$ N. Perpendicular components combine by the Pythagorean theorem. The 3-4-5 relationship scaled by 10 gives the resultant directly.
3. C — $Re = VD/\nu = (1)(0.05)/(1.0 \times 10^{-6}) = 50{,}000$. The Reynolds number is the ratio of inertial to viscous forces. A value this high confirms turbulent pipe flow.
4. D — $R = 5{,}729.58/D = 5{,}729.58/5 = 1{,}146$ ft. The arc-definition degree of curve is the central angle subtending a 100-ft arc. Smaller degrees of curve correspond to flatter, larger-radius curves.
5. B — $F = P(1 + i)^n = 5{,}000(1.08)^3 = 5{,}000 \times 1.2597 = \$6{,}299$. Compound interest grows the present sum geometrically. Each year's interest is earned on the accumulated balance.
6. B — $S = bh^2/6 = (150)(300^2)/6 = 2.25 \times 10^6$ mm³. The section modulus relates moment to extreme-fiber bending stress. The depth term is squared, so depth governs flexural capacity.
7. A — LRFD applies load factors above 1.0 and resistance factors below 1.0 to provide reliability-based safety margins. It separates load uncertainty from strength uncertainty. This is the prevailing modern design philosophy for steel and concrete.
8. C — Since $3^4 = 81$, $x = 4$. The exponent equals the logarithm base 3 of 81. Recognizing powers of 3 gives the result by inspection.
9. C — $V = Q/A = 4/(2 \times 1) = 2$ m/s. Average velocity is discharge divided by flow area. The rectangular section makes the area simply width times depth.
10. D — $a = v^2/r = 15^2/50 = 225/50 = 4.5$ m/s². Centripetal acceleration points toward the center of the curve. It scales with the square of speed, making speed the dominant factor.
11. A — Granular activated carbon adsorbs dissolved organic compounds responsible for taste and odor. Its large surface area binds these molecules. It does not remove hardness, grit, or dissolved oxygen.
12. D — HI = benchmark elevation + backsight = 100.00 + 2.45 = 102.45 m. The height of instrument establishes the reference plane for subsequent foresights. Foresight readings are then subtracted from the HI to get point elevations.
13. B — $\varphi = \arctan(\tau/\sigma) = \arctan(60/100) = 31°$. For a cohesionless sand ($c = 0$), the friction angle is the slope of the failure envelope. The shear strength is purely frictional.
14. C — DDB rate = 2/6 = 0.333, so year-1 depreciation = $0.333 \times 80{,}000 = \$26{,}667$. Double-declining-balance applies twice the straight-line rate to the current book value. Salvage value is not subtracted before applying the rate.
15. B — Each cable carries 600/2 = 300 N by symmetry. The two parallel vertical cables share the load equally. Vertical equilibrium requires their tensions to sum to the weight.
16. A — $h = P/\gamma = 200/9.81 = 20.4$ m. Pressure head converts pressure into an equivalent column height. Dividing by water's specific weight yields meters of water.
17. D — Time-mean speed is always greater than or equal to space-mean speed because it weights faster vehicles more heavily. The two are equal only when all speeds are identical. Space-mean speed is the appropriate measure for flow-density relationships.
18. B — Maximum shear in a uniformly loaded simple beam occurs at the supports, equal to the reactions. Shear decreases linearly to zero at midspan. The supports therefore govern shear design.
19. A — Hypotenuse $= \sqrt{(5^2 + 12^2)} = \sqrt{169} = 13$. The Pythagorean theorem gives the hypotenuse from the two legs. This is the classic 5-12-13 right triangle.

20. D — $Cu = D_{60}/D_{10} = 0.6/0.1 = 6$. The uniformity coefficient measures the spread of particle sizes. A higher value indicates a well-graded soil with a wide size range.
21. A — The (P/G) factor finds the present worth of a series increasing by a constant amount each period. It handles arithmetic gradients such as steadily rising maintenance costs. A geometric gradient, by contrast, grows by a constant percentage.
22. A — $a = g \sin\theta = 9.81 \times \sin 30° = 9.81 \times 0.5 = 4.9$ m/s². On a frictionless incline, only the gravity component along the slope drives motion. Mass cancels out of the acceleration.
23. D — Bernoulli's equation expresses conservation of mechanical energy per unit weight along a streamline for ideal flow. Pressure, velocity, and elevation heads trade off while their sum stays constant. Friction or pump terms must be added for real systems.
24. C — $\text{Sum} = (n - 2) \times 180° = (6 - 2) \times 180° = 720°$. This polygon relationship provides the angular closure check. The measured sum is compared with 720° to find angular error.
25. D — An eccentric axial load produces both direct compression and a bending moment equal to the load times its eccentricity. The combined stress is the sum of axial and flexural components. This governs the design of beam-columns.
26. B — Population variance $= [(2-4)^2 + (4-4)^2 + (6-4)^2]/3 = (4 + 0 + 4)/3 = 2.67$. Variance is the mean of the squared deviations from the mean. Dividing by n (not n−1) gives the population value.
27. C — A pile driven to refusal in dense sand transmits load mainly by end bearing at its tip. The dense bearing stratum provides high tip resistance. Skin friction contributes a smaller share in this case.
28. B — The internal rate of return is the discount rate at which net present worth equals zero. At that rate, discounted benefits exactly equal discounted costs. Comparing IRR to the MARR determines acceptability.
29. A — Friction head loss rises with increasing velocity (squared in Darcy-Weisbach) and increasing pipe length. Longer pipes and higher velocities both add resistance. Larger diameters and smoother walls reduce loss.
30. D — Under ideal conditions, a basic freeway lane has a capacity of about 2,400 passenger cars per hour per lane (HCM). This represents maximum sustainable flow before breakdown. Real capacity is reduced by trucks, grades, and lane width.
31. C — $\delta = PL/(AE) = (30{,}000 \times 3{,}000)/(300 \times 200{,}000) = 1.5$ mm. Axial elongation is proportional to load and length and inversely proportional to area and modulus. Consistent N-and-mm units yield millimeters.
32. D — A cable carrying only its self-weight hangs as a catenary, the curve of a uniformly heavy flexible chain. A uniformly distributed horizontal load would instead produce a parabola. The distinction matters for cable and suspension design.
33. B — A grit chamber removes heavy inorganic solids such as sand and gravel by controlled settling. This protects downstream pumps and equipment from abrasion. Organic matter is intentionally kept in suspension for later biological treatment.
34. C — The (A/P, 1%, 24) factor converts the present loan amount into 24 equal monthly payments. It is the capital recovery factor for the given rate and number of periods. This is the standard loan amortization calculation.
35. D — At $x = 3$, $y = 2(3) - 1 = 5$. Substituting into the line equation gives the y-value. The graph confirms the line passes through (3, 5).
36. A — Effective stress governs a soil's shear strength and volume-change behavior, per Terzaghi's principle. Strength and settlement depend on intergranular contact stress, not total stress. This is the central concept of soil mechanics.

37. C — Kinematic viscosity $\nu = \mu/\rho$, the dynamic viscosity divided by density. It expresses momentum diffusivity and appears in the Reynolds number. Its units are length squared per time.
38. C — Total lost time = 4 s × 2 phases = 8 s per cycle. Lost time accumulates once per phase from startup delay and clearance. It reduces the effective green available for movement.
39. B — Concrete cover shields the reinforcing steel from corrosion and provides fire resistance and bond. Adequate cover prevents moisture and chlorides from reaching the bars. Insufficient cover leads to spalling and durability problems.
40. C — A 4-year payback means the cumulative savings equal the initial investment after 4 years. It measures how quickly capital is recovered, not project life or return. Cash flows after payback are not considered.
41. C — Two equal, opposite, parallel forces on different lines of action form a couple, producing pure rotation. Their net force is zero, but their moment is nonzero. The couple moment is the same about every point.
42. A — The derivative of ln(x) is 1/x. This follows directly from the definition of the natural logarithm. It is a fundamental result used throughout integration and growth problems.
43. C — Velocity ratio = $(D_1/D_2)^2 = (100/50)^2 = 4$ by continuity. Halving the diameter quarters the area, so velocity quadruples. Mass conservation forces the speed increase.
44. D — The compression index Cc is the slope of the void-ratio versus log-effective-stress curve in the virgin compression range. It quantifies how much a soil compresses per log cycle of stress. It is central to consolidation settlement estimates.
45. A — An acceleration lane lets entering vehicles build up to mainline speed before merging into traffic. This reduces speed differentials and merge conflicts. It improves both safety and operations at ramps.
46. B — In a replacement study, the existing asset's relevant value is its current market value, the opportunity cost of keeping it. The original cost is a sunk cost and is ignored. This avoids the common error of using book value.
47. B — $a = F/m = 20/5 = 4$ m/s². Newton's second law gives acceleration as net force divided by mass. The result is independent of the body's velocity.
48. C — Transverse shear stress in a rectangular beam peaks at the neutral axis and is zero at the extreme fibers. The parabolic distribution follows from the shear formula $\tau = VQ/(Ib)$. The maximum equals 1.5 times the average shear stress.
49. B — Stadia distance equals the rod interval times the stadia interval factor, typically about 100. The instrument's optics fix this multiplying constant. This allows rapid approximate distance measurement.
50. D — A hydraulic jump converts supercritical (fast, shallow) flow to subcritical (slow, deep) flow, dissipating energy in turbulence. It forms downstream of spillways and gates. The energy loss protects channels from erosion.
51. C — For a central point load, the moment diagram is triangular, zero at the supports and maximum (PL/4) at midspan. Shear is constant on each half, so the moment varies linearly. This is a fundamental beam-loading case.
52. D — With equal first cost and life, lower annual operating cost yields the lower equivalent uniform annual cost. EUAC captures both capital recovery and operating expenses. The alternative with the smallest EUAC is preferred.
53. A — $45° \times (\pi/180°) = \pi/4$ radians ≈ 0.785. Converting degrees to radians multiplies by π/180. This is a common reference angle.

54. C — An OCR greater than 1 means the soil's preconsolidation pressure exceeds its current overburden stress, indicating past loading was heavier. Such overconsolidated soils settle less under added load. Stress history strongly affects compressibility.
55. D — Rectangular weir discharge varies with head to the 3/2 power ($Q \propto H^{1.5}$). This arises from integrating velocity over the flow depth. The relationship makes weirs convenient flow-measuring devices.
56. D — Crash rate is normalized per million vehicle-miles traveled to account for exposure. This allows fair comparison among sites with different traffic volumes. Raw crash counts alone can be misleading.
57. B — A planar truss is internally determinate when $m = 2j - 3$. The relation balances member forces against the available equilibrium equations. Fewer members make it unstable; more make it indeterminate.
58. D — Inflation is handled correctly by keeping the dollar basis and interest-rate basis consistent, either both real or both market (nominal). Mixing real cash flows with a market rate produces errors. This consistency rule is the key to inflation analysis.
59. D — $\omega = v/r = 8/0.4 = 20$ rad/s. For rolling without slipping, angular velocity equals the center velocity divided by the radius. Smaller wheels spin faster at the same travel speed.
60. C — A slender column fails when the load reaches the Euler critical buckling load, an elastic instability. This load depends on stiffness and the square of slenderness, not material strength alone. Below this load the column remains stable.
61. C — Manning's equation makes velocity proportional to $R^{(2/3)}$. The hydraulic radius captures the channel's flow efficiency. Combined with the slope to the one-half power, it gives the velocity.
62. A — The No. 200 sieve (0.075 mm) divides coarse-grained from fine-grained soils in standard classification. Material retained is sand or coarser; material passing is silt or clay. This split governs which classification procedure applies.
63. B — Level-loop misclosure is judged against an allowable error that scales with the route length (often a constant times the square root of distance). Longer loops permit larger absolute closure errors. This standardizes accuracy requirements.
64. A — Endowment = $A/i = 4{,}000/0.05 = \$80{,}000$. The capitalized cost of a perpetual annual payment is the payment divided by the interest rate. The principal generates the annual disbursement forever.
65. D — Area = ½ × base × height = ½ × 4 × 4 = 8. The region under $y = x$ from 0 to 4 is a right triangle. Integrating x from 0 to 4 gives the same result.
66. C — Vertical component = $10 \times \sin(36.87°) = 10 \times 0.6 = 6$ kN. In a 3-4-5 orientation, the sine of 36.87° is 0.6. The horizontal component would be $10 \times 0.8 = 8$ kN.
67. C — Ductility lets a steel member undergo large plastic deformation before fracture, giving warning and redistributing load. This energy absorption is vital under overload and seismic demand. Brittle behavior, by contrast, fails suddenly.
68. D — Specific energy equals flow depth plus velocity head ($y + V^2/2g$), measured relative to the channel bottom. It is minimized at critical flow for a given discharge. This concept underlies open-channel control sections.
69. A — Rapid loading of saturated clay is analyzed with undrained, total-stress ($\varphi = 0$) methods because pore water cannot drain quickly. The short-term strength is governed by undrained shear strength. Long-term conditions require a drained analysis.

70. A — The clearance interval combines the yellow change interval and the all-red interval. Together they let the intersection clear before conflicting movements receive green. Proper timing prevents right-angle collisions.
71. B — Depreciation lowers taxable income, creating a depreciation tax shield equal to the depreciation times the tax rate. This reduces taxes owed and improves after-tax cash flow. It is a key consideration in economic analysis.
72. C — P(at least one) = 1 − P(neither) = 1 − (0.5)(0.5) = 0.75. The complement of "neither event occurs" gives the answer efficiently. Independence allows multiplying the individual non-occurrence probabilities.
73. C — Principal stresses act on planes where the shear stress is zero. These planes carry the maximum and minimum normal stresses. Mohr's circle locates them at its horizontal-axis intercepts.
74. A — Hydraulic depth equals flow area divided by the top (water-surface) width. It represents an average depth for open-channel energy and Froude-number calculations. For a wide rectangular channel it approaches the actual depth.
75. B — An idealized pin connection transfers force but not moment, allowing free rotation. This assumption simplifies frame analysis. A fixed connection, in contrast, transfers both force and moment.
76. A — $K_a = \tan^2(45° - \varphi/2) = \tan^2(30°) = 0.333$ for $\varphi = 30°$. The active coefficient reduces the at-rest pressure as the wall yields outward. It is used to size retaining structures.
77. A — GPS determines position by measuring signal travel times from at least four satellites and trilaterating. Each travel time converts to a range using the speed of light. Precise satellite clocks make this possible.
78. C — $\Delta KE = \frac{1}{2}m(v_1^2 - v_2^2) = \frac{1}{2} \times 1{,}000 \times (400 - 100) = 150{,}000$ J = 150 kJ. Kinetic energy depends on the square of speed. The energy difference is dissipated by braking.
79. B — A present lump sum is carried forward with (F/P) and a uniform series with (F/A); summing both gives the total future worth. Each cash-flow type uses its matching factor. Combining factors handles mixed cash flows.
80. A — The solution to $dy/dx = ky$ is $y = Ce^{kx}$, exponential growth or decay. Separating variables and integrating yields the natural-exponential form. The constant C is set by the initial condition.
81. D — With two equal loads P at the third points, each reaction is P, and the maximum moment in the central region is P(L/3) = PL/3. The moment is constant between the loads. This is a standard third-point loading result.
82. B — A pump's operating point lies where the pump head-capacity curve intersects the system (head-loss) curve. At that flow, the head supplied equals the head required. Changing the system curve shifts the operating point.
83. A — Footings on sand settle almost immediately upon loading because the high permeability allows rapid drainage. There is little time-dependent consolidation. This contrasts sharply with clays.
84. B — Superelevation tilts the pavement inward to counteract the centrifugal force on a vehicle traversing a curve. The banking lets gravity help balance the lateral demand. It reduces reliance on side friction.
85. D — The "do nothing" alternative provides the baseline against which incremental investments are measured. It represents continuing with no new expenditure. Each alternative's incremental benefit is judged relative to it.

86. B — The derivative of x^2 is $2x$, so the slope at $x = 3$ is $2 \times 3 = 6$. The tangent slope equals the instantaneous rate of change. Evaluating the derivative at the point gives the value.
87. D — A bolt under combined tension and shear is checked with an interaction equation that limits the two effects together. Neither stress alone captures the reduced capacity. This prevents premature combined-stress failure.
88. C — Total dynamic head includes static lift, friction (and minor) losses, and the velocity head. It represents the total energy the pump must add. Summing these terms sizes the pump correctly.
89. C — Chlorine reacting with natural organic matter forms trihalomethanes, a regulated disinfection byproduct. These compounds are health concerns at elevated levels. Controlling organics before chlorination limits their formation.
90. D — Slenderness ratio = effective length / radius of gyration (KL/r). It measures a column's tendency to buckle. Higher ratios indicate more slender, buckling-prone members.
91. B — The phreatic surface is the top seepage flow line in an earth dam, where pore pressure equals atmospheric. Below it the soil is saturated and under positive pressure. Its position controls seepage and stability.
92. A — With no air resistance, a projectile's horizontal velocity stays constant because no horizontal force acts. Gravity affects only the vertical component. The horizontal and vertical motions are independent.
93. D — A geometric gradient series grows by a constant percentage each period. This models costs that escalate proportionally, such as inflation-driven expenses. An arithmetic gradient instead grows by a fixed dollar amount.
94. B — The median is the line inside the box, located at 50. The box spans the interquartile range from Q1 (30) to Q3 (70). The whiskers extend to the data extremes at 10 and 90.
95. B — A uniform straight rod has its center of gravity at its geometric midpoint. Uniform mass distribution places the centroid at the center. This is where the rod would balance.
96. C — Flow is subcritical when the Froude number is less than 1, indicating deep, tranquil flow controlled from downstream. At Fr = 1 the flow is critical, and above 1 it is supercritical. The regime affects how disturbances propagate.
97. A — A fillet weld is designed for shear on its effective throat, the smallest cross-section of the weld. Capacity equals the throat area times the allowable shear strength. This governs weld sizing regardless of load direction.
98. B — The shrinkage limit is the water content below which further drying produces no additional volume reduction. At this point the soil is at its minimum volume. It marks the boundary between the semisolid and solid states.
99. D — The k-factor is the proportion of AADT that occurs during the design hour. It converts daily traffic into an hourly design volume. Typical values fall in the range of about 0.08 to 0.12.
100. A — Alternatives with unequal lives are compared over a common study period, often the least common multiple of their lives. This ensures equal service is compared on both sides. The annual-cost method is an alternative that achieves the same fairness.
101. D — The integral of $1/x$ is $\ln|x| + C$. The absolute value covers negative x values. This is a standard antiderivative used widely in analysis.
102. A — Linear momentum is conserved in a collision when external forces are negligible during the brief impact. Internal collision forces cancel as equal and opposite pairs. Kinetic energy may or may not be conserved.

103. A — In a thin-walled cylinder, hoop stress is twice the longitudinal stress ($\sigma_h = pr/t$ versus $\sigma_l = pr/2t$). The circumferential direction carries the greater load. This is why such vessels tend to split along their length.

104. D — Darcy-Weisbach head loss is proportional to the velocity squared through the $V^2/2g$ term. Doubling velocity quadruples the friction loss. This nonlinear dependence makes velocity a key design variable.

105. B — Bearing capacity increases with footing width and with the soil friction angle, per the $N\gamma$ and Nq terms. Wider footings and stronger soils mobilize more resistance. A rising water table reduces capacity by lowering effective stress.

106. D — A moment-resisting frame carries lateral loads through bending at rigid beam-column joints. The rigid connections transfer moments to develop frame action. This provides stiffness without diagonal bracing or shear walls.

107. A — A topographic survey maps both horizontal positions and elevations, shown as contour lines depicting relief. It conveys the three-dimensional shape of the terrain. This supports grading, drainage, and site design.

108. A — The benefit-cost ratio method is most often applied to public-sector projects, where social benefits are weighed against costs. A ratio above 1.0 indicates economic justification. It is standard practice in government infrastructure evaluation.

109. B — Mean of a binomial = $np = 10 \times 0.3 = 3.0$. The expected number of successes equals trials times success probability. This is a basic property of the binomial distribution.

110. C — An engineer aware of an imminent danger to the public must promptly notify the appropriate authority, consistent with the duty to hold public safety paramount. This obligation overrides client or employer preferences. Timely reporting can prevent harm.