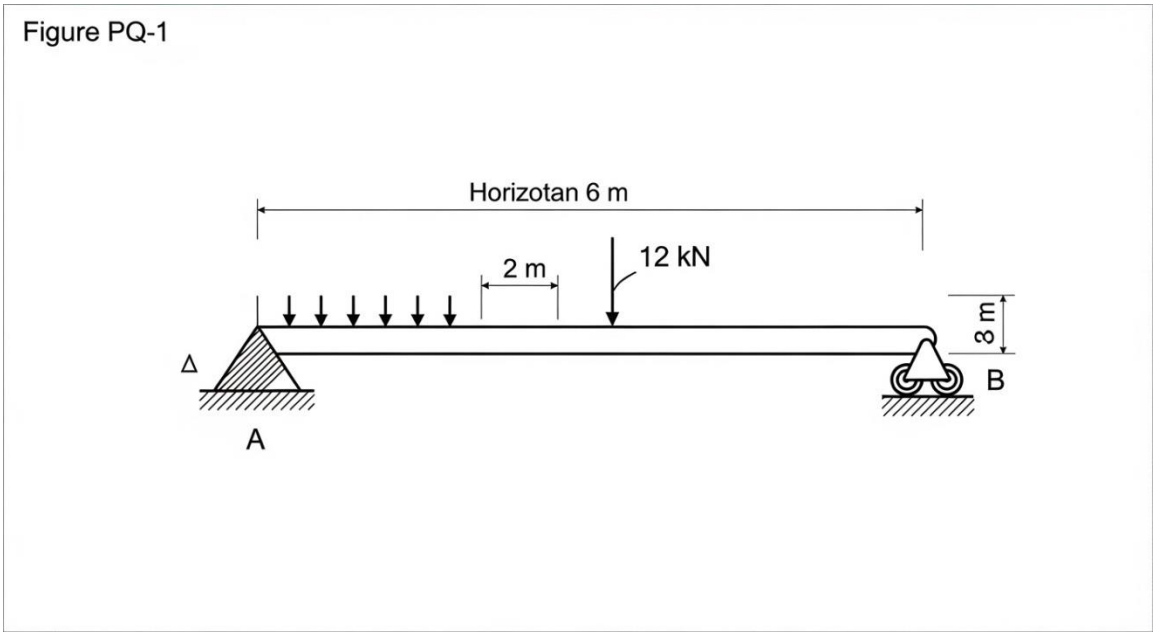
PRACTICE EXAM 8: FE CIVIL SIMULATION (110 QUESTIONS)

1. A simply supported beam spans 6 m with a pin at the left support A and a roller at the right support B. A 12 kN downward point load acts 2 m from A. What is the reaction at A?

Figure PQ-1



A. 8.0 kN

B. 4.0 kN

C. 6.0 kN

D. 12.0 kN

2. A 25 mm diameter steel bar carries an axial tensile force of 60 kN. What is the normal stress (use area = $\pi d^2/4$)?

A. 96 MPa

B. 122 MPa

C. 153 MPa

D. 245 MPa

3. Water flows through a 0.15 m diameter pipe at an average velocity of 2 m/s. What is the volumetric flow rate?

A. 0.0177 m^3/s

B. 0.0353 m^3/s

C. 0.0707 m^3/s

D. 0.300 m^3/s

4. A rectangular open channel is 3 m wide and flows at a depth of 1 m. What is the hydraulic radius?

A. 1.00 m

B. 3.00 m

C. 0.50 m

D. 0.60 m

5. A fully saturated clay has a water content of 40% and a specific gravity of solids of 2.70. Assuming S = 100%, what is the void ratio?

A. 0.40

B. 0.74

C. 1.08

D. 2.70

6. A closed traverse has a latitude misclosure of +0.3 m and a departure misclosure of −0.4 m. What is the linear misclosure?

A. 0.10 m

B. 0.30 m

C. 0.40 m

D. 0.50 m

7. A vehicle decelerates uniformly at 4.9 m/s² from a speed of 20 m/s. What is the braking distance?

A. 20.4 m

B. 10.2 m

C. 40.8 m

D. 81.6 m

8. What is the present worth of $1,000 to be received in 5 years at an interest rate of 10% per year?

A. $909

B. $500

C. $621

D. $1,610

9. A projectile is launched at 30 m/s at 30° above the horizontal. What is the time to reach maximum height (g = 9.81 m/s²)?

A. 1.53 s

B. 3.06 s

C. 0.77 s

D. 2.65 s

10. Which limit state in a steel W-shape beam involves the compression flange displacing laterally and twisting?

A. Local web yielding

B. Shear rupture failure

C. Lateral-torsional buckling

D. Flange local buckling

11. The slump test performed on fresh concrete is used to assess the mix's:

A. Compressive strength gain

B. Entrained air content

C. Aggregate gradation quality

D. Workability (consistency)

12. Solve the system $x + y = 10$ and $x - y = 4$. What is the value of x?

A. 3

B. 5

C. 7

D. 10

13. An engineer accepts a gift of significant value from a vendor whose product they are actively evaluating. This situation most clearly creates:

A. A conflict of interest

B. A valid licensing credential

C. An enforceable warranty

D. A professional endorsement

14. A pipe expands from a cross-sectional area of 0.01 m^2 to 0.04 m^2. If the velocity at the inlet is 8 m/s, what is the velocity at the outlet?

A. 32 m/s

B. 2 m/s

C. 8 m/s

D. 0.5 m/s

15. A soil profile has 3 m of moist sand (γ = 18 kN/m³) above the water table, then 2 m of saturated sand (γ_sat = 20 kN/m³). What is the effective vertical stress at a depth of 5 m (γ_w = 9.81 kN/m³)?

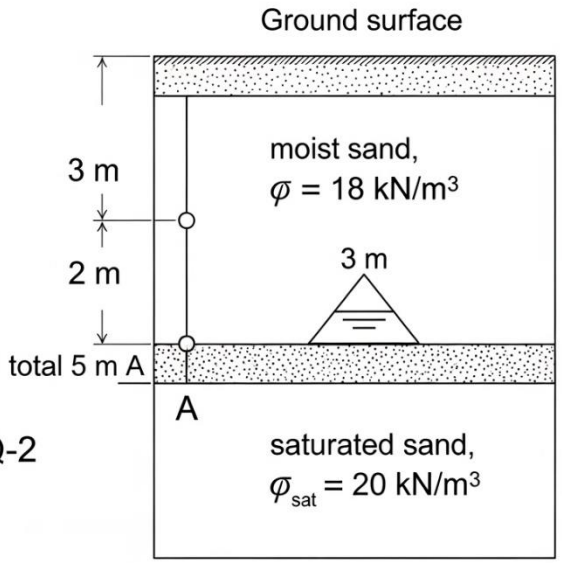


Figure PQ-2

A. 94.0 kPa

B. 54.0 kPa

C. 40.0 kPa

D. 74.4 kPa

16. A horizontal curve has a radius of 300 m, with e + f = 0.15. What is the maximum safe speed (V = √[gR(e + f)])?

A. 21 m/s

B. 45 m/s

C. 10 m/s

D. 30 m/s

17. Equal annual deposits of $2,000 are made for 10 years at 5%. Using (F/A, 5%, 10) = 12.578, what is the future value?

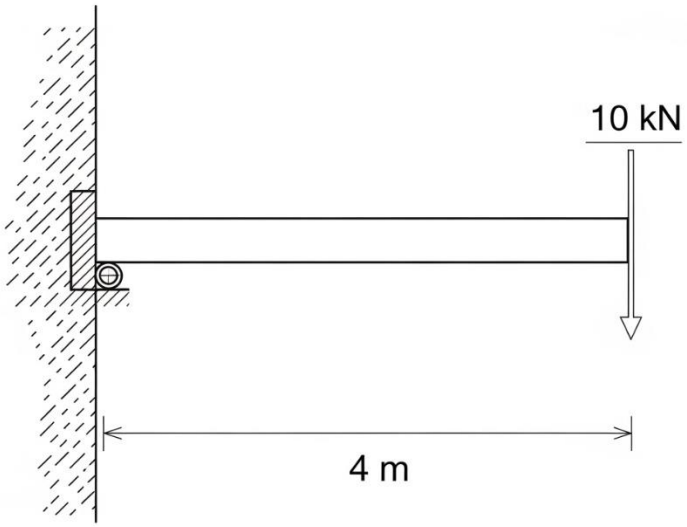
A. $20,000

B. $12,578

C. $30,000

D. $25,156

18. A cantilever beam 4 m long is fixed at the left wall and carries a 10 kN downward point load at its free end. What is the maximum bending moment?



A. 40 kN·m

B. 10 kN·m

C. 20 kN·m

D. 0 kN·m

19. The Euler critical buckling stress of a slender column is proportional to:

A. (KL/r)

B. $(KL/r)^2$

C. $1/(KL/r)^2$

D. $\sqrt{(KL/r)}$

20. Evaluate the definite integral of $3x^2$ from 0 to 2.

A. 8

B. 12

C. 6

D. 4

21. A flywheel rotates at 120 rpm. What is its angular velocity in rad/s?

A. 7.54 rad/s

B. 12.57 rad/s

C. 120 rad/s

D. 20 rad/s

22. A storm with a 25-year return period has an annual exceedance probability of approximately:

A. 4%

B. 25%

C. 0.4%

D. 40%

23. Chlorine demand in water treatment is best defined as:

A. Applied chlorine minus the measured residual

B. The total residual after 30 minutes

C. The free chlorine present at the tap

D. The combined chlorine fraction only

24. In US-customary stationing, a point at station 12+50 is what distance from station 0+00?

A. 125 ft

B. 1,025 ft

C. 1,250 ft

D. 12,500 ft

25. A 5 kN force acts due east and a 12 kN force acts due north at the same point. What angle does the resultant make with the east axis?

A. 22.6°

B. 45.0°

C. 50.2°

D. 67.4°

26. In ACI reinforced-concrete design, the strength reduction factor φ for tension-controlled flexure is:

A. 0.65

B. 0.75

C. 0.90

D. 1.00

27. The hydraulic grade line (HGL) at a point represents the sum of:

A. Pressure head plus elevation head

B. Velocity head plus elevation head

C. Total head minus elevation head

D. Velocity head plus pressure head

28. A square footing 2 m × 2 m carries a column load of 800 kN. What is the contact bearing pressure?

A. 400 kPa

B. 200 kPa

C. 100 kPa

D. 800 kPa

29. A heavily loaded truck on a sustained 2% upgrade typically:

A. Accelerates and gains speed steadily on the grade

B. Maintains its free-flow speed without difficulty

C. Experiences a reduced required stopping distance

D. Loses speed, possibly warranting a climbing lane

30. A bond with a face value of $1,000 pays a 6% annual coupon. What is each annual interest payment?

A. $600

B. $1,000

C. $106

D. $60

31. For a normal distribution, approximately what percentage of values lie within one standard deviation of the mean?

A. 68%

B. 95%

C. 99.7%

D. 50%

32. A two-force member in an ideal pin-connected truss carries only:

A. Bending moment

B. Shear force

C. Axial force

D. Torsion

33. The maximum midspan deflection of a simply supported beam under a uniform load w over span L is:

A. $wL^4/(8EI)$

B. $wL^3/(48EI)$

C. $wL^4/(384EI)$

D. $5wL^4/(384EI)$

34. In fully rough turbulent pipe flow, the Darcy friction factor depends primarily on:

A. Reynolds number only

B. Fluid density only

C. Relative roughness (ε/D)

D. Pipe length only

35. Proper compaction of a soil generally increases its:

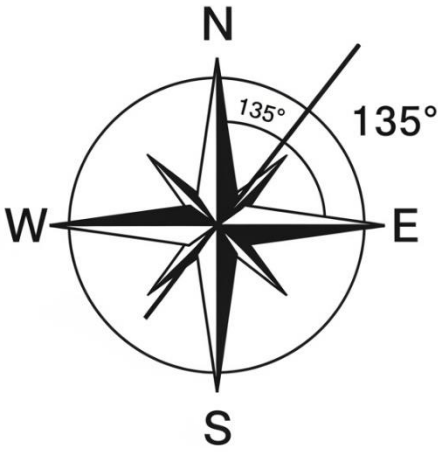
A. Void ratio and permeability

B. Dry density and shear strength

C. Water content only

D. Compressibility and settlement

36. A survey line has an azimuth of 135°. What is its equivalent bearing?



A. N 45° E

B. N 45° W

C. S 45° W

D. S 45° E

37. A signalized movement has an effective green time of 36 s within a 90 s cycle. What is the g/C ratio?

A. 0.25

B. 0.40

C. 0.50

D. 0.60

38. The principal useful gas generated during anaerobic digestion of wastewater sludge is:

A. Carbon dioxide

B. Methane

C. Hydrogen sulfide

D. Nitrogen gas

39. The capitalized cost of a perpetual annual disbursement A at interest rate i is:

A. A/i

B. $A \times i$

C. $A \times (1 + i)$

D. $A/(1 + i)$

40. A particle in uniform circular motion has constant speed but:

A. A continuously changing velocity direction

B. Zero acceleration throughout the motion

C. A constant linear momentum vector

D. No net force acting on it

41. What is the derivative of $\sin(x)$?

A. $-\cos(x)$

B. $\cos(x)$

C. $-\sin(x)$

D. $\tan(x)$

42. The elastic section modulus S of a beam relates the bending moment to the:

A. Transverse shear stress

B. Midspan deflection

C. Axial stress

D. Maximum bending stress

43. What is the gauge pressure at the bottom of a 10 m column of oil with specific gravity 0.85?

A. 98.1 kPa

B. 83.4 kPa

C. 10.0 kPa

D. 8.5 kPa

44. The plasticity index of a fine-grained soil is computed as:

A. Plastic limit minus shrinkage limit

B. Liquid limit minus plastic limit

C. Liquid limit minus shrinkage limit

D. Plastic limit plus liquid limit

45. The required length of a vertical sag curve is most commonly controlled by:

A. Daytime passing sight distance

B. Pavement cross-drainage slope

C. Centrifugal force on vehicles

D. Headlight sight distance at night

46. A cash flow that increases by a constant amount each period is analyzed using the:

A. Sinking fund factor

B. Capital recovery factor

C. Arithmetic gradient factor

D. Single-payment factor

47. The moment produced by a couple is:

A. The same about every point

B. Zero everywhere in the body

C. Dependent on the reference point

D. Equal to the net applied force

48. A 1 m long rod elongates 0.5 mm under axial load. What is the axial strain?

A. 5×10^{-4}

B. 5×10^{-3}

C. 0.5

D. 5×10^{-5}

49. A weir installed in an open channel is used primarily to:

A. Reduce sediment load only

B. Increase the channel roughness

C. Measure or control discharge

D. Prevent evaporation losses

50. In the Unified Soil Classification System, the symbol CL denotes:

A. Low-plasticity clay

B. Well-graded gravel

C. High-plasticity silt

D. Poorly graded sand

51. An electronic distance measuring (EDM) instrument determines distance using:

A. A graduated steel tape

B. Triangulated angle pairs

C. The barometric pressure gradient

D. The phase or travel time of a signal

52. Superelevation runoff is the roadway length needed to:

A. Transition from zero to full superelevation

B. Provide adequate stopping sight distance

C. Drain surface water off the pavement

D. Develop the full design speed of traffic

53. Evaluate $\log_2(32)$.

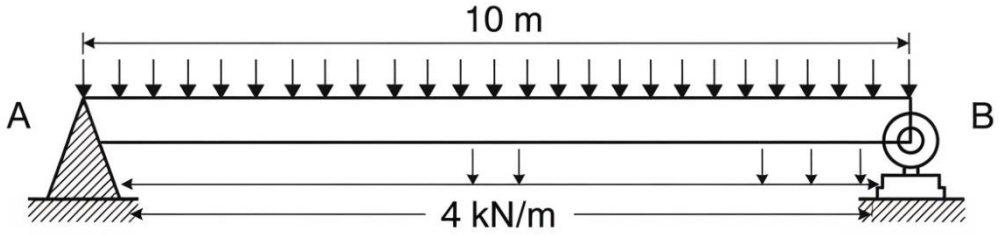
A. 16

B. 2

C. 6

D. 5

54. A beam is pinned at A (left) and on a roller at B (right), spanning 10 m, with a uniform load of 4 kN/m over the full span. What is the reaction at A?



A. 40 kN

B. 10 kN

C. 4 kN

D. 20 kN

55. Cavitation in a centrifugal pump begins when the local pressure falls to:

A. Atmospheric pressure

B. The fluid's vapor pressure

C. The pump discharge pressure

D. Twice the suction head

56. Terzaghi's bearing capacity equation includes terms for cohesion, surcharge, and:

A. Soil unit weight and footing width

B. The pore pressure ratio only

C. The allowable settlement tolerance

D. The groundwater flow velocity

57. When comparing two alternatives by incremental rate of return, the higher-cost option is justified if its incremental ROR:

A. Is negative

B. Equals exactly zero

C. Exceeds the MARR

D. Is less than the MARR

58. The acceleration due to gravity in US-customary units is approximately:

A. 9.81 ft/s²

B. 16.1 ft/s²

C. 32.2 ft/s²

D. 62.4 ft/s²

59. The centroid of a semicircle of radius r lies at what distance from its flat (diameter) edge?

A. $4r/(3\pi)$

B. $r/2$

C. $3r/(4\pi)$

D. $2r/\pi$

60. Mohr's circle is used in mechanics of materials to determine:

A. Beam deflection limits

B. Column buckling loads

C. Principal and maximum shear stresses

D. Fatigue life cycles

61. The hydraulic radius of a circular pipe flowing full with diameter D is:

A. D

B. D/2

C. D/4

D. D/8

62. The Greenshields traffic model assumes the relationship between speed and density is:

A. Exponential

B. Parabolic

C. Constant

D. Linear

63. Hardness in a water supply is caused primarily by:

A. Calcium and magnesium ions

B. Sodium and potassium ions

C. Dissolved oxygen content

D. Suspended organic solids

64. A flow net is a graphical tool used to analyze:

A. Slope stability factor of safety

B. Field compaction control

C. Bearing capacity directly

D. Seepage flow through soil

65. If the MARR is 10% and a project's internal rate of return is 8%, the project is:

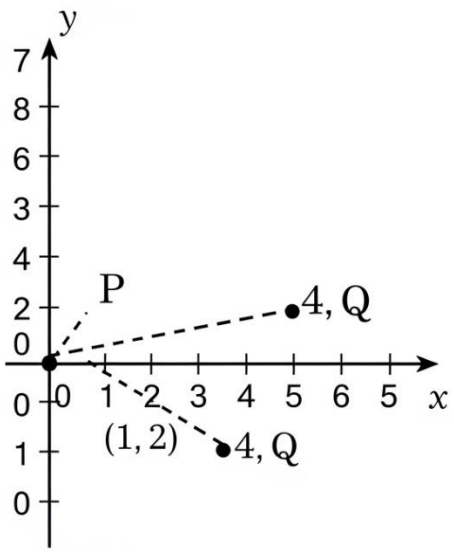
A. Not economically acceptable

B. Exactly at breakeven

C. Highly profitable to pursue

D. Acceptable as proposed

66. In the coordinate plane shown, what is the distance between points P(1, 2) and Q(4, 6)?



A. 4

B. 5

C. 6

D. 7

67. Prestressing concrete with high-strength tendons introduces:

A. Additional permanent dead load

B. A permanent torsional twist

C. Compression offsetting tensile stresses

D. Shear-only reinforcement

68. The Reynolds number represents the ratio of:

A. Inertial to viscous forces

B. Pressure to gravity forces

C. Viscous to surface-tension forces

D. Elastic to inertial forces

69. A 1,200 kg vehicle traveling at 30 m/s is brought to rest in 5 s. What is the average braking force?

A. 3,600 N

B. 6,000 N

C. 7,200 N

D. 36,000 N

70. The angle of internal friction of a cohesionless sand is most directly obtained from:

A. A direct shear or triaxial test

B. A standard Proctor compaction test

C. A hydrometer grain-size analysis

D. An Atterberg limits test

71. A vertical angle measured upward from the horizontal plane is called:

A. An angle of elevation

B. An azimuth

C. A deflection angle

D. An angle of depression

72. Compared with straight-line depreciation, the declining-balance method produces:

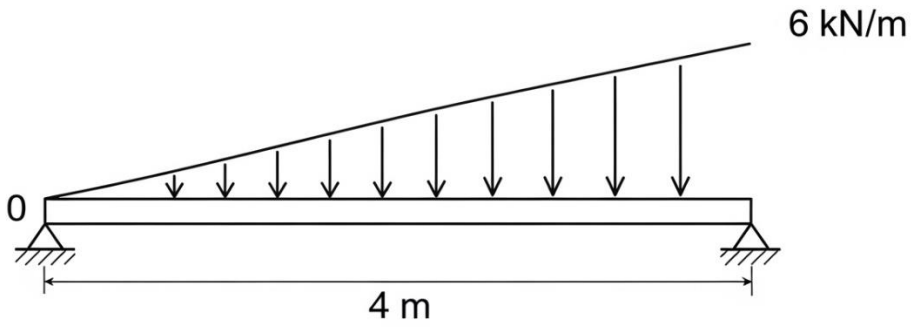
A. Equal deductions each year

B. Smaller deductions early on

C. No deduction in the first year

D. Larger deductions in early years

73. A triangular distributed load varies linearly from 0 at the left end to 6 kN/m at the right end over a 4 m span. What is the total resultant force?



A. 24 kN

B. 12 kN

C. 6 kN

D. 10 kN

74. The thermal axial strain in an unrestrained bar subjected to a temperature change ΔT is:

A. αT^2 only

B. $E \times \Delta T$

C. $\alpha \times \Delta T$

D. $\Delta T / \alpha$

75. A venturi meter determines flow rate by relating discharge to:

A. The fluid temperature rise

B. The pressure difference across a constriction

C. The pipe wall roughness

D. The total elevation change

76. The distance between successive vehicles measured front-bumper to front-bumper is the:

A. Gap

B. Clearance

C. Headway time

D. Spacing

77. Maximum contaminant levels (MCLs) for drinking water are established by:

A. The local water utility board

B. The US EPA under the Safe Drinking Water Act

C. The state highway department

D. The American Concrete Institute

78. Soil liquefaction is most strongly associated with:

A. Dry dense gravels under static load

B. Saturated loose sands under cyclic loading

C. Overconsolidated stiff clays

D. Compacted fill above the water table

79. The simple payback period method of evaluation ignores:

A. The initial investment cost

B. The annual operating savings

C. The salvage value only

D. The time value of money

80. What are the roots of $x^2 - 5x + 6 = 0$?

A. 1 and 6

B. −2 and −3

C. 2 and 3

D. 5 and 6

81. The moment of inertia of a solid circular cross-section of diameter d is:

A. $\pi d^4/32$

B. $\pi d^4/64$

C. $\pi d^3/32$

D. $\pi d^2/4$

82. A pump delivers 0.05 m^3/s of water against a total head of 20 m. What is the water power output?

A. 1.0 kW

B. 4.9 kW

C. 9.8 kW

D. 20 kW

83. A normally consolidated clay has a preconsolidation pressure that is:

A. Much greater than the overburden stress

B. Equal to the current overburden stress

C. Always equal to zero

D. Independent of stress history

84. The design hourly volume (DHV) is conventionally taken as the:

A. 30th highest hourly volume of the year

B. Average of all hourly volumes

C. Peak 15-minute flow rate

D. Annual average daily traffic

85. A nominal annual rate of 12% compounded monthly has an effective annual rate of:

A. 12.00%

B. 12.68%

C. 1.00%

D. 6.17%

86. A uniform ladder leans against a frictionless wall and a rough floor. The reaction force from the wall is:

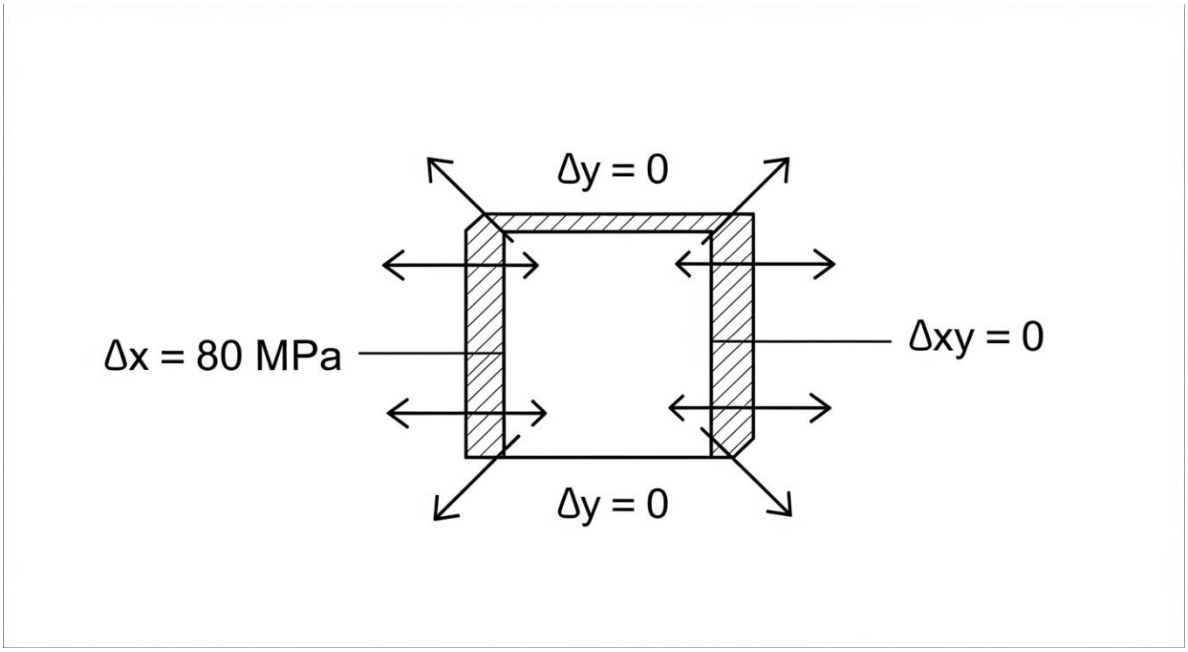
A. Vertical only

B. Directed along the ladder

C. Horizontal (normal to the wall)

D. Zero in all directions

87. For the stress state shown, σx = 80 MPa, σy = 0, and τxy = 0. What is the maximum in-plane shear stress?



A. 80 MPa

B. 0 MPa

C. 40 MPa

D. 160 MPa

88. In fully developed laminar flow through a circular pipe, the velocity profile across the cross-section is:

A. Parabolic

B. Uniform (flat)

C. Logarithmic

D. Linear

89. The coefficient of permeability k of a soil has the same units as:

A. Velocity (length per time)

B. Force per unit area

C. A dimensionless ratio

D. Volume per unit time

90. A flexible pavement transmits wheel loads to the subgrade primarily by:

A. A single rigid slab acting in bending

B. Steel dowel bars across joints

C. Tensioned reinforcing tendons

D. Successive granular layers spreading the load

91. The book value of a depreciating asset at any time equals:

A. The current market resale price

B. Original cost minus accumulated depreciation

C. The salvage value plus interest

D. The replacement cost today

92. If a fair coin is flipped three times, what is the probability of getting exactly two heads?

A. 1/2

B. 3/8

C. 1/4

D. 1/8

93. In Allowable Stress Design of steel, the allowable strength equals the nominal strength divided by:

A. The resistance factor φ

B. The applied load factor

C. The safety factor Ω

D. The modulus of elasticity

94. Mercury has a specific gravity of about 13.6. Its density is approximately:

A. 1,360 kg/m^3

B. 136 kg/m^3

C. 1,000 kg/m^3

D. 13,600 kg/m^3

95. The factor of safety for a soil slope is defined as the ratio of:

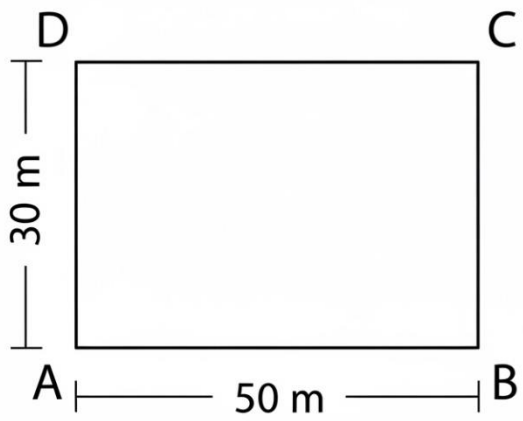
A. Driving forces to resisting forces

B. Resisting forces to driving forces

C. Cohesion to the friction angle

D. Total stress to effective stress

96. A rectangular parcel measures 50 m along its base and 30 m along its left side. What is its area?



A. 80 m²

B. 160 m²

C. 150 m²

D. 1,500 m²

97. If the nominal interest rate is 8% and inflation is 3%, the approximate real (inflation-adjusted) interest rate is:

A. 11%

B. 24%

C. 5%

D. 2.67%

98. A spring with a stiffness of 200 N/m is compressed 0.1 m. How much elastic potential energy is stored?

A. 20 J

B. 2 J

C. 1 J

D. 0.5 J

99. A 100 N force acts at 60° above the x-axis. What is its x-component?

A. 50 N

B. 86.6 N

C. 100 N

D. 60 N

100. The polar moment of inertia J of a solid circular shaft of diameter d is:

A. $\pi d^4/64$

B. $\pi d^4/16$

C. $\pi d^4/32$

D. $\pi d^3/16$

101. The head loss at a sudden enlargement in a pipe is classified as a:

A. Minor (local) loss

B. Major friction loss

C. Pump energy gain

D. Pure elevation head change

102. In AASHTO pavement design, the ESAL parameter represents:

A. The maximum legal axle weight

B. A single passenger-car trip

C. The annual rainfall load

D. Equivalent single-axle loads over the design life

103. Secondary wastewater treatment is designed primarily to remove:

A. Coarse grit and screenings

B. Biodegradable organics via biological action

C. Dissolved nitrogen and phosphorus fully

D. All pathogenic viruses completely

104. The uniform-series present-worth factor (P/A) is used to compute:

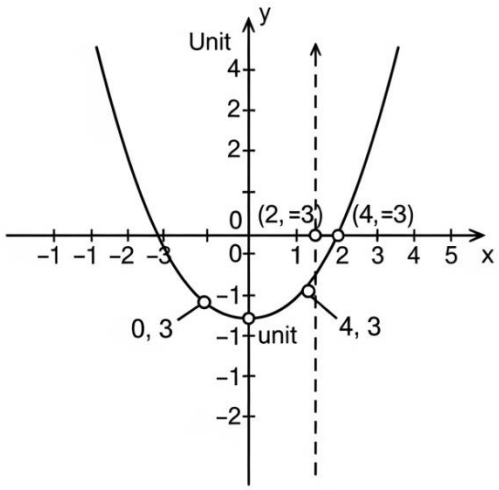
A. The future value of a single payment

B. The annual cost of repaying a loan

C. The present value of equal annual payments

D. A single future lump sum amount

105. The graph shows an upward-opening parabola with its vertex at (2, −1). What is the equation of the axis of symmetry?



A. x = 2

B. y = −1

C. x = −1

D. y = 2

106. Compression reinforcement is added to a doubly reinforced concrete beam mainly to:

A. Resist shear at the supports

B. Eliminate the need for stirrups

C. Increase ductility and reduce deflection

D. Replace the tension reinforcement

107. In open-channel flow, the Froude number compares inertial forces to:

A. Viscous forces

B. Surface-tension forces

C. Elastic forces

D. Gravitational forces

108. An increase in effective stress applied to a saturated clay layer produces:

A. Immediate rebound (swelling)

B. A decrease in shear strength

C. Liquefaction of the clay

D. Time-dependent consolidation settlement

109. For a wheel rolling without slipping, the velocity of the point in contact with the ground is:

A. Equal to the center velocity

B. Zero at the instant of contact

C. Twice the center velocity

D. Equal to the angular velocity

110. Sensitivity analysis in an engineering economic study examines:

A. Only the salvage value estimate

B. The exact future inflation rate

C. The contractor's profit margin

D. How input changes affect the outcome

Exam 8 Answer Key and Explanations

1. A — $R_A = Pb/L = 12 \times 4 / 6 = 8.0$ kN. For a simply supported beam, each reaction is the load times the distance to the far support divided by the span. The support nearer the load carries the larger share, which is why A exceeds the reaction at B (4 kN).
2. B — $\sigma = P/A = 60{,}000 \text{ N} / (\pi/4 \times 25^2) = 60{,}000 / 490.9 = 122$ MPa. Normal stress equals axial force divided by the circular cross-sectional area. Using the correct $\pi d^2/4$ area is the key step that separates the right answer from the distractors.
3. B — $Q = AV = (\pi/4 \times 0.15^2) \times 2 = 0.01767 \times 2 = 0.0353$ m³/s. Flow rate is cross-sectional area times average velocity. Forgetting to square the radius or omitting velocity produces the other choices.

4. D — $R = A/P = (3 \times 1) / (3 + 2 \times 1) = 3 / 5 = 0.60$ m. Hydraulic radius is flow area divided by wetted perimeter, and only the channel bottom plus the two side depths form the wetted perimeter. The open top is not counted.
5. C — For full saturation, $e = wG_s/S = 0.40 \times 2.70 / 1.0 = 1.08$. The phase relationship $Se = wG_s$ links water content and void ratio when S = 100%. This is a fundamental check on saturated soil behavior.
6. D — Linear misclosure = $\sqrt{(0.3^2 + 0.4^2)} = \sqrt{0.25} = 0.50$ m. The closure error is the vector resultant of the latitude and departure misclosures. Recognizing the 3-4-5 triangle gives the answer directly.
7. C — $d = V^2/(2a) = 20^2 / (2 \times 4.9) = 400 / 9.8 = 40.8$ m. Braking distance from uniform deceleration uses kinematics with final velocity zero. This component feeds directly into stopping sight distance design.
8. C — $P = F/(1 + i)^n = 1{,}000 / 1.1^5 = 1{,}000 / 1.6105 = \$621$. Present worth discounts a single future amount back to today. Higher interest or longer time reduces present value, which is why $621 is well below the future $1,000.
9. A — $t = V \sin\theta / g = 30 \times 0.5 / 9.81 = 1.53$ s. Time to peak height occurs when the vertical velocity component reaches zero. Doubling this gives total flight time, which is why 3.06 s is a tempting distractor.
10. C — Lateral-torsional buckling is the limit state where an unbraced compression flange moves sideways and the section twists. It governs beams with insufficient lateral bracing of the compression flange. Adequate bracing or a higher unbraced-length limit prevents it.
11. D — The slump test measures workability (consistency) of fresh concrete by the vertical drop after the cone is lifted. It is a field control for batch-to-batch uniformity, not a strength or air-content test. Excessive slump usually signals too much water.
12. C — Adding the two equations gives $2x = 14$, so $x = 7$. Eliminating y by addition solves the linear system directly. Substituting back yields $y = 3$.
13. A — Accepting a valuable gift from a vendor under evaluation creates a conflict of interest because it can compromise impartial professional judgment. Engineering codes require avoiding situations where personal gain influences technical decisions. Disclosure or refusal of the gift is the proper response.
14. B — By continuity, $V_2 = V_1A_1/A_2 = 8 \times 0.01 / 0.04 = 2$ m/s. As area increases, velocity decreases proportionally for incompressible flow. A fourfold area increase produces a fourfold velocity decrease.
15. D — Effective stress = total stress − pore pressure = $(18 \times 3 + 20 \times 2) - (9.81 \times 2) = 94 - 19.6 = 74.4$ kPa. Only the saturated zone below the water table generates pore pressure. Subtracting it from total stress gives the intergranular stress that controls strength.
16. A — $V = \sqrt{[gR(e + f)]} = \sqrt{(9.81 \times 300 \times 0.15)} = \sqrt{441.5} = 21$ m/s. Maximum safe curve speed balances superelevation and side friction against centrifugal demand. Larger radius or higher e + f permits higher speeds.
17. D — $F = A(F/A, 5\%, 10) = 2{,}000 \times 12.578 = \$25{,}156$. The uniform-series compound-amount factor accumulates equal annual deposits to a future value. The result exceeds the simple sum of $20,000 because of compounding.
18. A — Maximum moment in a tip-loaded cantilever is $M = PL = 10 \times 4 = 40$ kN·m, occurring at the fixed support. The moment is zero at the free end and grows linearly toward the wall. The fixed end is the critical design section.

19. C — Euler stress $\sigma_{cr} = \pi^2 E/(KL/r)^2$ is inversely proportional to the square of the slenderness ratio. Slender columns therefore buckle at much lower stresses. This relationship underlies all elastic column-stability design.
20. A — $\int_0^2 3x^2\,dx = [x^3]_0^2 = 8 - 0 = 8$. The antiderivative of $3x^2$ is x^3, evaluated between the limits. The cubic growth makes the area concentrate toward the upper limit.
21. B — $\omega = 120 \times 2\pi / 60 = 12.57$ rad/s. Converting revolutions per minute requires multiplying by 2π radians per revolution and dividing by 60 seconds. Skipping the 2π factor produces the distractor 20.
22. A — Annual exceedance probability = $1/T = 1/25 = 0.04 = 4\%$. Return period and annual probability are reciprocals. A longer return period means a rarer, lower-probability event.
23. A — Chlorine demand equals the chlorine applied minus the residual that remains after the reaction period. It represents the amount consumed by oxidizable substances in the water. Knowing the demand sets the required dose to achieve a target residual.
24. C — Station 12+50 means 1,200 + 50 = 1,250 ft from the origin in the US system. Each full station equals 100 ft, with the figure after the plus sign giving the additional feet. This convention is fundamental to alignment layout.
25. D — $\theta = \arctan(12/5) = \arctan(2.4) = 67.4°$ from the east axis. The resultant direction comes from the ratio of the north component to the east component. The larger northward force tilts the resultant well above 45°.
26. C — The ACI strength reduction factor φ for tension-controlled flexural members is 0.90. This accounts for variability in materials and construction while rewarding ductile behavior. Lower φ values apply to compression-controlled or shear conditions.
27. A — The hydraulic grade line equals pressure head plus elevation head (the piezometric head). It lies below the energy grade line by the velocity head. The HGL shows where water would rise in piezometers along the system.
28. B — Bearing pressure = load/area = 800 / (2 × 2) = 200 kPa. Contact pressure is the applied load divided by the footing's plan area. Increasing footing size lowers the pressure delivered to the soil.
29. D — A heavy truck loses speed on a sustained upgrade because gravity opposes its limited power-to-weight ratio, and a climbing lane may be warranted where the speed drop is large. This protects the operating speed of following passenger vehicles. The speed-reduction criterion governs the warrant.
30. D — Annual coupon = face value × rate = 1,000 × 0.06 = $60. The coupon payment is based on the bond's face value, not its market price. The $1,000 principal is returned separately at maturity.
31. A — Approximately 68% of values fall within one standard deviation of the mean in a normal distribution. About 95% lie within two and 99.7% within three (the empirical rule). This underpins confidence intervals and quality control limits.
32. C — A two-force member carries only axial force, either tension or compression, with no bending or shear. Equilibrium requires the two end forces to be equal, opposite, and collinear. This assumption is the basis of truss analysis by joints and sections.
33. D — Maximum deflection of a uniformly loaded simple beam is $5wL^4/(384EI)$ at midspan. The fourth-power span dependence makes deflection highly sensitive to length. This is the standard serviceability formula for this load case.
34. C — In fully rough turbulent flow, the friction factor depends only on relative roughness ε/D, becoming independent of Reynolds number. This is the flat region on the right of the Moody diagram. Smoother pipes yield lower friction factors in this regime.

35. B — Compaction increases dry density and shear strength while reducing void ratio, permeability, and future settlement. Expelling air brings soil particles into closer contact. This improves the load-bearing performance of fills and subgrades.
36. D — An azimuth of 135° lies in the southeast quadrant, giving a bearing of S 45° E. Bearings in the southeast quadrant are measured as the angle from south toward east, equal to 180° − 135° = 45°. Converting between azimuths and bearings is a core surveying skill.
37. B — g/C = 36 / 90 = 0.40. The ratio of effective green time to cycle length sets the capacity available to a movement. A higher g/C ratio provides more green and greater throughput.
38. B — Anaerobic digestion of sludge produces methane as the primary energy-rich gas, along with carbon dioxide. The methane (biogas) can be captured to power plant operations. This stabilizes the sludge and reduces its volume and odor.
39. A — Capitalized cost of a perpetual uniform cost is A/i, the present worth of an infinite annuity. As the number of periods approaches infinity, the present-worth factor approaches 1/i. This applies to perpetual maintenance or endowment problems.
40. A — In uniform circular motion the speed is constant but the velocity direction continually changes, producing centripetal acceleration toward the center. A net inward force is therefore required. Constant speed does not mean zero acceleration.
41. B — The derivative of sin(x) is cos(x). This is a standard result from the limit definition of the derivative. Its sign and phase shift are essential in oscillation and wave analysis.
42. D — Section modulus S relates bending moment to maximum bending stress through $\sigma = M/S$. A larger S yields a lower stress for the same moment, indicating greater flexural efficiency. It is the key geometric property in beam selection.
43. B — $P = \rho gh = (0.85 \times 1{,}000) \times 9.81 \times 10 = 83.4$ kPa. The fluid's specific gravity scales water's density before applying the hydrostatic relation. A lighter fluid produces less pressure than water at the same depth.
44. B — Plasticity index = liquid limit − plastic limit. It measures the range of water content over which a soil remains plastic. A higher PI indicates more clay and greater volume-change potential.
45. D — Sag vertical curve length is typically governed by headlight sight distance, since nighttime visibility limits how far ahead a driver can see. The headlight beam and its upward divergence define the controlling geometry. Comfort and drainage criteria usually govern less often.
46. C — A constant period-to-period increase is modeled with the arithmetic gradient factor (P/G or A/G). It converts a uniformly increasing series into an equivalent present or annual value. This handles costs that rise steadily over time.
47. A — The moment of a couple is constant about every point because the two equal and opposite forces produce a pure rotational effect. Its magnitude equals one force times the perpendicular separation. This independence from location is a defining property of couples.
48. A — Strain = elongation/length = 0.5 mm / 1,000 mm = 5×10^{-4}. Strain is the dimensionless ratio of deformation to original length. Consistent units are essential, since mixing mm and m produces order-of-magnitude errors.
49. C — A weir measures or controls discharge in an open channel by relating flow to the head over its crest. The head-discharge relationship makes it a simple flow-measuring structure. It also sets upstream water levels.
50. A — In USCS, CL designates clay of low plasticity (liquid limit below 50). The first letter denotes the dominant soil type and the second its plasticity. This classification guides expected engineering behavior.

51. D — An EDM instrument measures distance by timing or comparing the phase of a transmitted and returned electromagnetic signal. The travel time converts to distance using the speed of light. This replaced taping for precise long-distance measurement.
52. A — Superelevation runoff is the length over which the pavement transitions from a flat (zero-superelevation) section to full superelevation. It provides a smooth, comfortable rate of cross-slope change entering a curve. Too short a runoff causes abrupt, uncomfortable rotation.
53. D — $\log_2(32) = 5$ because $2^5 = 32$. The logarithm answers what power of the base yields the argument. Recognizing powers of two gives the result by inspection.
54. D — Reaction = $wL/2 = 4 \times 10 / 2 = 20$ kN at each support by symmetry. A uniform load splits equally between two equidistant supports. The total 40 kN is shared evenly.
55. B — Cavitation begins when local pressure drops to the fluid's vapor pressure, forming vapor bubbles that collapse violently. This occurs typically at the pump suction where pressure is lowest. Maintaining adequate net positive suction head prevents it.
56. A — Terzaghi's equation sums cohesion, surcharge, and a soil-weight term that includes footing width B and unit weight γ. The three terms (N_c, N_q, N_γ) capture the soil's shear resistance contributions. This forms the basis of shallow-foundation capacity analysis.
57. C — In incremental analysis, the added investment of the higher-cost option is justified only if its incremental rate of return exceeds the MARR. Comparing increments avoids the ranking errors that arise from comparing individual rates of return. The MARR is the acceptance threshold.
58. C — Standard gravity in US-customary units is 32.2 ft/s². This is the customary counterpart to 9.81 m/s². It appears throughout dynamics and fluid problems in English units.
59. A — The centroid of a semicircle lies at $4r/(3\pi)$ from the flat diameter edge. This standard result is used in computing areas, first moments, and hydrostatic forces. The centroid sits closer to the diameter than to the arc.
60. C — Mohr's circle graphically determines principal stresses and the maximum shear stress from a general stress state. The circle's center gives the average normal stress and its radius gives the maximum shear. It is fundamental to failure and transformation analysis.
61. C — For a circular pipe flowing full, $R = A/P = (\pi D^2/4)/(\pi D) = D/4$. The full-flow geometry simplifies neatly to one-quarter of the diameter. This value is used directly in Manning and Darcy computations.
62. D — The Greenshields model assumes a linear speed-density relationship, which yields a parabolic flow-density curve. The linear assumption gives a simple, foundational macroscopic traffic model. Free-flow speed and jam density are its two anchor points.
63. A — Water hardness is caused chiefly by dissolved calcium and magnesium ions. These ions form scale and reduce soap effectiveness. Softening processes target their removal.
64. D — A flow net is a graphical solution of two-dimensional seepage, mapping flow lines and equipotential lines. From the number of flow channels and drops it gives seepage quantity and uplift pressures. It applies to dams, sheet piles, and excavations.
65. A — With an IRR of 8% below a MARR of 10%, the project does not meet the minimum return and is not acceptable. The IRR must equal or exceed the MARR for acceptance. The shortfall indicates the investment underperforms the required rate.
66. B — Distance = $\sqrt{[(4-1)^2 + (6-2)^2]} = \sqrt{(9+16)} = \sqrt{25} = 5$. The distance formula applies the Pythagorean theorem to coordinate differences. This is the classic 3-4-5 triangle.
67. C — Prestressing introduces internal compression that counteracts the tensile stresses produced by service loads. This keeps the concrete largely in compression, controlling cracking and deflection. It allows longer spans and slenderer members than conventional reinforcement.

68. A — Reynolds number is the ratio of inertial forces to viscous forces, $\rho VD/\mu$. Its magnitude predicts whether flow is laminar or turbulent. Low values indicate viscous-dominated laminar flow.
69. C — $F = m\Delta v/t = 1{,}200 \times 30 / 5 = 7{,}200$ N. The impulse-momentum relation gives average force as the momentum change divided by the stopping time. Longer stopping time would reduce the force.
70. A — The friction angle of cohesionless sand is measured by direct shear or triaxial testing, which apply controlled normal and shear stresses. These tests yield the shear strength envelope. Proctor, hydrometer, and Atterberg tests address other properties.
71. A — A vertical angle measured upward from the horizontal is an angle of elevation. Measured downward, it would be an angle of depression. These define line-of-sight inclinations in surveying.
72. D — Declining-balance depreciation applies a constant rate to a shrinking book value, producing larger deductions in early years. This accelerated pattern front-loads tax benefits. The deductions taper off as the book value declines.
73. B — Resultant of a triangular load = ½ × base × peak = ½ × 4 × 6 = 12 kN. The total force equals the area under the load diagram. Its line of action passes through the centroid of the triangle.
74. C — Free thermal strain is $\alpha \times \Delta T$, the product of the coefficient of thermal expansion and the temperature change. If the bar is unrestrained, no thermal stress develops. Restraint converts this strain into stress.
75. B — A venturi meter relates discharge to the pressure difference between the inlet and the constricted throat using Bernoulli and continuity. The throat acceleration creates a measurable pressure drop. It is an accurate, low-loss flow measurement device.
76. D — Spacing is the distance between successive vehicles measured front bumper to front bumper. Headway, by contrast, is the corresponding time interval. Spacing and density are reciprocally related.
77. B — Maximum contaminant levels are set by the US EPA under the Safe Drinking Water Act. These enforceable standards protect public health in public water systems. States may adopt equal or stricter limits.
78. B — Liquefaction occurs in saturated, loose sands subjected to cyclic (seismic) loading, when rising pore pressure reduces effective stress to near zero. The soil temporarily behaves like a fluid. Dense or well-drained soils resist this behavior.
79. D — The simple payback method ignores the time value of money and any cash flows after payback is reached. It measures only how quickly the initial cost is recovered. This makes it a screening tool rather than a rigorous economic measure.
80. C — Factoring $x^2 - 5x + 6 = (x - 2)(x - 3)$ gives roots 2 and 3. The roots sum to 5 and multiply to 6, matching the coefficients. Checking by substitution confirms both satisfy the equation.
81. B — Moment of inertia of a circle is $I = \pi d^4/64$ about a centroidal axis. The fourth-power dependence on diameter means small diameter changes greatly affect stiffness. This value is used in bending and deflection of round members.
82. C — $P = \rho gQH = 1{,}000 \times 9.81 \times 0.05 \times 20 = 9{,}810$ W ≈ 9.8 kW. Water power is the product of specific weight, flow rate, and head. Dividing by pump efficiency would give the larger required input power.
83. B — A normally consolidated clay has a preconsolidation pressure equal to its current effective overburden stress, meaning it has never carried a higher load. Overconsolidated clays, in contrast, were once loaded more heavily. This distinction governs settlement predictions.

84. A — The design hourly volume is conventionally the 30th-highest hourly volume of the year, balancing economy against rare peaks. Designing for the absolute peak would be wasteful. This volume drives lane and capacity decisions.
85. B — $i_{eff} = (1 + 0.12/12)^{12} - 1 = (1.01)^{12} - 1 = 12.68\%$. Monthly compounding raises the effective annual rate above the 12% nominal rate. More frequent compounding always increases the effective rate.
86. C — A frictionless wall can only push perpendicular to its surface, so its reaction on the ladder is horizontal. Friction would be needed for any vertical component, which the smooth wall cannot provide. The rough floor supplies the vertical and friction forces.
87. C — $\tau_{max} = (\sigma x - \sigma y)/2 = (80 - 0)/2 = 40$ MPa for this uniaxial state. With no shear and one principal stress zero, the maximum shear is half the applied normal stress. It acts on planes oriented 45° to the loading axis.
88. A — Fully developed laminar pipe flow has a parabolic velocity profile, maximum at the center and zero at the wall. This results from the balance of pressure and viscous shear. The average velocity is half the centerline maximum.
89. A — The coefficient of permeability k carries units of velocity (length per time) because it represents a seepage velocity per unit hydraulic gradient. In Darcy's law $q = kiA$, the gradient i is dimensionless. This is why k is reported in cm/s or m/s.
90. D — A flexible pavement spreads wheel loads to the subgrade through successive granular and asphalt layers, distributing stress over a wider area with depth. Unlike a rigid slab, it does not act primarily in bending. Each layer reduces the stress reaching the layer below.
91. B — Book value equals original cost minus accumulated depreciation at any point in the asset's life. It is an accounting value, not necessarily the market price. It approaches the salvage value at the end of the depreciation period.
92. B — $P(\text{exactly 2 heads}) = C(3,2)/2^3 = 3/8$. There are three favorable arrangements out of eight equally likely outcomes. The binomial coefficient counts the ways to place the two heads.
93. C — In ASD, allowable strength equals nominal strength divided by the safety factor Ω. LRFD instead multiplies nominal strength by the resistance factor φ. The two methods provide comparable reliability through different formats.
94. D — Density = SG × 1,000 = 13.6 × 1,000 = 13,600 kg/m³. Specific gravity multiplies the density of water to give the substance's density. Mercury's high value reflects its use in manometers and barometers.
95. B — The slope factor of safety is the ratio of resisting forces (or moments) to driving forces (or moments). A value above 1.0 indicates stability. Designers require a margin well above 1.0 to account for uncertainty.
96. D — Area = 50 × 30 = 1,500 m². The area of a rectangle is the product of its two side lengths. The smaller distractors result from confusing perimeter or using only one dimension.
97. C — The approximate real rate is nominal minus inflation = 8% − 3% = 5%. The exact Fisher value is about 4.85%, so 5% is the standard approximation. Real return measures purchasing-power growth after inflation.
98. C — $PE = \frac{1}{2}kx^2 = \frac{1}{2} \times 200 \times 0.1^2 = 1.0$ J. Spring potential energy depends on the square of the deflection. Doubling the compression would quadruple the stored energy.
99. A — $F_x = F\cos\theta = 100 \times \cos 60° = 100 \times 0.5 = 50$ N. The horizontal component uses the cosine of the angle from the x-axis. The vertical component would use the sine, giving 86.6 N.

100. C — Polar moment of inertia of a solid circular shaft is $J = \pi d^4/32$, twice the bending moment of inertia. It governs torsional shear stress and angle of twist. The fourth-power dependence again makes diameter dominant.

101. A — Loss at a sudden enlargement is a minor (local) loss caused by flow separation and turbulence at the geometry change. Minor losses are computed from a loss coefficient times the velocity head. They are distinct from distributed friction losses along the pipe.

102. D — ESAL represents equivalent single-axle loads accumulated over the pavement's design life, converting mixed traffic into standard 18-kip axle passes. It quantifies the cumulative damage demand. This drives the required pavement structural number or thickness.

103. B — Secondary treatment removes biodegradable organic matter (measured as BOD) through biological processes such as activated sludge or trickling filters. Microorganisms consume the dissolved and colloidal organics. Grit removal is primary, and full nutrient removal is tertiary.

104. C — The P/A factor converts a uniform series of equal annual payments into a single present value. It is used to price loans, leases, and annuities. Its reciprocal, A/P, recovers capital as equal payments.

105. A — For a parabola with vertex at $(2, -1)$, the axis of symmetry is the vertical line $x = 2$ through the vertex. The axis of symmetry of a vertical parabola is always $x = h$, the vertex's x-coordinate. The curve mirrors across this line.

106. C — Compression steel in a doubly reinforced beam increases ductility and reduces long-term (creep) deflection. It also lets a shallow beam carry more moment when section depth is limited. Shear is still handled separately by stirrups.

107. D — The Froude number compares inertial forces to gravitational forces in open-channel flow. A value of 1 marks critical flow, separating subcritical from supercritical regimes. Gravity, not viscosity, is the relevant restoring force at a free surface.

108. D — Increasing effective stress on a saturated clay causes time-dependent consolidation settlement as pore water slowly drains. The low permeability of clay makes this a gradual process. The settlement magnitude depends on the compression index and stress increase.

109. B — For rolling without slipping, the contact point has zero instantaneous velocity, acting as the instantaneous center of rotation. The center of the wheel moves at v while the top moves at 2v. This kinematic condition defines pure rolling.

110. D — Sensitivity analysis evaluates how variations in input estimates change the economic outcome, revealing which assumptions most affect the decision. It identifies the parameters that warrant the most accurate estimation. This manages uncertainty in projections.